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The symposium examined the interrelationship between training technology, policy problems and policy planning. Training was traced from the inception, development, test and evaluation stages through the translation into policy and the implementation of that policy within selected groups within DOD, FCC, ONR, Honeywell Corp., Giant Foods, and U. of Maryland. Topics included ~~were~~

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SYMPOSIUM PROCEEDINGS

OF THE

POTOMAC CHAPTER

HUMAN FACTORS SOCIETY

"TRAINING: TECHNOLOGY TO POLICY"

HELD AT

GEORGE WASHINGTON UNIVERSITY CLUB
CLOYD HECK MARVIN CENTER
H and 21st STREETS, N. W.
WASHINGTON, D. C.

FOREWORD

The papers that make up this report deal with research and policy problems in education and training. The papers were presented at a symposium held by the Potomac Chapter of the Human Factors Society, at George Washington University in Washington, DC, 25 May 1976.

Since 1968 the Potomac Chapter has held an annual symposium, usually one day in length, and these symposia have most often produced important but undocumented presentations. Attendance usually consists of fifty to sixty professionals from academia, industry and government. Therefore, only a few human factors practitioners, and other interested parties, normally benefit from this information exchange. Because the topic of this symposium is important it was decided that it would benefit the training community if the prepared papers were published, and the overall proceedings made available to a wider audience.

Concerning the importance of the topic area, it merits comment that a recent overview document by the National Institute of Education ("1976 Databook: The Status of Education Research and Development in the United States") states that Education is today the major occupation of 62.2 million people in the United States. That figure, along with the fact that more than $96 billion will be spent by educational institutions this year, lends credence to the contention that education is the Nation's largest enterprise. In the January 1974 issue of the Defense Management Journal it was reported that the annual direct costs of the Department of Defense education and training programs amount to $6 to $7 billion, with approximately 20 percent of the military personnel force in training at any one time. Within the Army Research Institute over two-thirds of our Research and Development program addresses training problems. Thus, this exchange of ideas that meetings such as this produce has the potential for providing benefits both to the defense community and the country as a whole, but only if such information is made readily available. That is the intent of this report.

J. E. UHLANER
Technical Director, ARI &
Chief Psychologist, US Army

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SYMPOSIUM COMMITTEE

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PURPOSE AND SCOPE

This year's symposium will examine the obscure interrelationship between training technology and policy in an attempt to illuminate how each affects the other. Human factors has impacted on product oriented, job-based training which is assessed in terms of specific performance standards, and has been described as the discipline's "growth industry." Results from this technology influence policy and planning, which in turn develop priorities for further research. A key aspect of this symposium, therefore, will be to trace training from the research phase (development, test, evaluation) through the process of translating the resultant technology into implementation policy to the impact of policy on training. Speakers from the representative areas will "tell it like it is" to portray the process.

LIST OF SPEAKERS

Mr. James D. Baker - Introduction *
Army Research Institute

Dr. Robert L. Hilliard - Keynote Address *
Federal Communications Commission

Dr. John A. Modrick *
Honeywell, Inc.

Dr. Irwin L. Goldstein *
University of Maryland

Mr. Ron Rivers
Giant Food, Inc.

Mr. Paul Barton
National Manpower Institute

Dr. Joseph L. Young *
Office of Naval Research

Dr. Bruce W. Knerr *
Army Research Institute

Dr. Joseph H. Kanner
Army Training and Doctrine Command

LTC Henry A. Taylor
Defense Directorate for Research and Engineering

*Papers included in symposium record

INTRODUCTION

TRAINING: TECHNOLOGY TO POLICY

James D. Baker

Army Research Institute

On May 25th, 1976 the Potomac Chapter of the Human Factors Society (POC-HFS) held its annual, all-day symposium at the Cloyd Heck Marvin Center of the George Washington University, Washington, D. C. The topic was "Training: Technology to Policy."

The purpose of this year's symposium was to examine the many facets of an area of human factors endeavor which has been described as the discipline's "growth industry"--training. The focus was on training (defined for purposes of this meeting as a structured learning environment which is product oriented, job-based and assessed in terms of ad hoc, specified performance standards) as opposed to educational endeavors which are more school-based, process oriented, general in nature and typically do not entail some validation/assessment procedure after graduation. Within the boundary condition of training, formal and on-the-job training were considered, as was general vs. specific skills orientations. A key aspect of this symposium was the attempt to trace training along a research, to development, to test and evaluation continuum with special attention being given to the process of translating the resultant technology into implementation policy.

The meeting was called to order promptly (to everyone's surprise) at 0900 by Ed Connelly of Omnemii, Inc., POC HFS Symposium Chairperson. After the usual and expected administrative announcements, Ed introduced Dr. Robert Hilliard who delivered the symposium's "charge,"

or opening comments (depending on whether you have a military or academic orientation). Bob is the Chief of the Educational Broadcasting Branch of the Federal Communication Commission, but, and perhaps of more importance for this meeting, he is also Chairman of the Educational Technology Subcommittee of the Federal Interagency Committee on Education. His opening remarks were filled with choice tidbits. My problem here is to tease out a few without doing harm to the total fabric of his presentation.

Dr. Hilliard called to the assembled group's attention the observation that three technological occurrences have dominated twentieth century man's life more than any other--transportation, energy and communication. Of these, communication may be the most important. The problem for us HFS-types is one of communication; to communicate to policy makers, in a meaningful fashion, the full impact of the "wonders" of our technology and to help them translate the findings into policy. Unless we can accomplish this our training technology will be accepted but applied only as band-aids--and it will be the first to go when money gets tight. Simply stated: we are faced with a problem of specialists communicating with generalists, and vice versa.

CONCEPTS, PROBLEMS AND POLICY

Dr. Kate Arbogast of the Department of Health, Education and Welfare (HEW) chaired the first session: Concepts, problems and

policy. Following the theme of the symposium, the session addressed the continuum of research to development to utilization/evaluation to policy, but with the topics being handled in a broad, general way.

The first paper in this session was presented by Dr. John "Tony" Modrick of Honeywell Inc. who also happens to be Chairperson of the HFS Training Technical Interest Group. The title of Tony's presentation was "Notes on a Sequence of Models from Research Through an Assessment of an Application." Among the many points he made, at least one was key to this observer. Tony noted that state-of-the-art is not a relevant term to the basic researcher since he (she) is primarily interested in theory building. Thus, the basic researcher is internally driven; he (she) sets his (her) own criteria. Tony also drove home a point made by Bob Hilliard, viz., that our technological innovations must be absorbed into broad policy if they are to survive, in one of his observations concerning the present status of computer-assisted instruction (CAI). Tony noted that, with few exceptions, CAI systems sit in the back of some large school room, looking great for the newspapers and sounding good on TV, but rarely are they an integral and critical component of an overall training system.

Tony was followed by Dr. Irwin L. Goldstein of the University of Maryland who discussed "Organizational Analysis and Its Meaning for Development and Evaluation of Training Programs." Because

Irv's presentation was a gold mine of ideas, it is tough to single out any one item for discussion here. I think, however, one basic theme in Irv's talk merits comment. As he noted, step one in the design of a training system must begin with a "need assessment" within the framework of the target organization. This must be followed by continuing assessment, feedback and revision to fine-tune the training system to the needs of the organization. Failure to take this requirement into consideration may account for why so many training programs have adopted the "fads" approach and subsequently died. The fads approach says--adopt whatever is fashionable today (e.g., role modelling, sensitivity training, etc.) and hope it works. Many of these fads would probably drop-out of the inventory rapidly if their feet were held to the fire of constant, hard-nosed evaluation.

Ron Rivers of Giant Food, Inc. (probably the largest supermarket chain in the Washington, D. C. area) presented next on "Breaking the Training Tradition." He began by stating that tradition has been the driving force in the processed food industry for years. Normally, you hire a clerk, let that person watch another clerk for ten minutes and from then on it is show-and-tell osmosis. With the expansion of its stores, a turnover rate of nearly 30% yearly and a perceived need on the part of the organization that a key slot was the district manager, the realization dawned that a requirement existed to break with tradition--formalize training. An exhaustive survey of how other food processing

organizations had handled this problem eventuated in the decision to go to the field and look (i.e., take an on-site, task analytic approach to the problem). The end result was a successfully structured, self-improvement program called MAIM: measurement (where are you): analysis (how do you get out of this rut); integration (get your program together) and maintenance (feedback to maintain your desired, "idealized" state).

The last speaker in the morning session was Paul Barton of the National Manpower Institute who addressed the problem of "Translating Social Research into Social Policy." He spoke from his long experience at the rarified level of national policy making while he was with the Department of Labor. He pointed out that the degree to which social science findings have influenced national policy is a moot point. Congress thinks they have had too much influence; social scientists think they have had too little. But he also noted that the social scientist is in a peculiar position in that it is hard for him to be treated in the same neutral fashion that one treats a physical scientist. A social science finding is a public finding and a political event. It is of news value and the resultant interpretations do not always coincide with the data. The policy maker who uses these findings is subject to the gnawing doubt of whether the implementation of this highly visible research will work. The number of variables are great and there are so many unknowns that we should not expect giant changes in society based on social science data alone. And the world goes on without us--policy leading to public

education decisions in the U.S. occurred without benefit of research findings. If we are to have impact on national policy we must provide timely, credible research findings to top level (secretary or White House level) policy makers in an understandable fashion. A large order for anyone.

COGNITION, COMPUTERS, CHANGES AND CASH

The afternoon session was chaired by yours truly and unfolded along the continuum of the symposium theme noted earlier while addressing the specifics of cognition, computers, changes and cash.

The opening speaker was Dr. Joseph Young of the Office of Naval Research. The title of his presentation was "Research on Cognitive Psychology Within a Training Framework." His main thrust was a description of basic research being conducted in the exotic world of generative computer-assisted instruction (CAI), i.e., CAI which generates instruction on-line from a data-base or representation of the subject matter and the applications of artificial-intelligence techniques to CAI. The work described attempts to develop generative CAI systems for tutoring strategies can be implemented in a computer. As an adjunct to this type of research, he described work addressing the problem of developing a curriculum information network. This is a formal means for specifying relationships between parts of a CAI curriculum. The

research is aimed at improving the effectiveness of tutorial CAI by comparing different algorithms for individualized selection of instructional material, based on the different student models within a curriculum information network.

Dr. Bruce Knerr of the Army Research Institute subsequently built upon this basic research presentation by describing a specific CAI application derived from Joe Young's exotic world in his talk on "Artificial Intelligence Techniques for Electronic Troubleshooting Training: Development and Evaluation." He described his on-going research effort directed toward developing and evaluating a minicomputer-based Adaptive Computerized Training System (ACTS) which combines principles of artificial intelligence, decision theory and adaptive computer-assisted instruction. The task selected for evaluation focuses on decision-making in electronic trouble-shooting. The ACTS incorporates an adaptive computer program which learns the student's diagnostic and decision value structure using a trainable network technique of pattern classification, compares this structure to that of an expert, and adapts the instructional sequence to eliminate discrepancies through the use of heuristic algorithms. An expected value model of decision-making is the basis of the student and instructor models which, with the task simulator and adaptive instructions, form the core of the ACTS. The instructor model also generates suggested actions in response to student

requests for assistance. The student's task is to troubleshoot a complex circuit by making test measurements, replacing the malfunctioning part, and making verification measurements. The student values of interest are those for information gained through the measurements, and for the replacement of circuit modules.

Dr. Knerr's paper was followed by a presentation from Dr. Joseph Kanner, Education Advisor, Headquarters U.S. Army Training and Doctrine Command. His paper had the intriguing title: "Chinese Syndrome in Behavioral Research--Some Proposals for Change." The title, as he developed it in his talk, reflected the "users resistance to change." He described how the Chinese have, for centuries, been invaded by others but, inevitably, the cultural impact of these invaders is short-lived; with the Chinese always reverting back to their old ways. In much the same manner, technologists keep invading the schools but, several years later, the schools are still the same. In keeping with the "fads" notion mentioned earlier, he used his own pioneering efforts in the use of educational TV as an instance of this Chinese syndrome. Dr. Kanner then took to task the world of CAI and managed to lather-up the assembled mass rather nicely. In all, it was a provocative presentation.

The final formal presentation was given by COL/Dr. Henry A. Taylor of the Defense Directorate for Research and Engineering (DDR&E).

He tackled the defense related research-to-policy problems in his presentation: "Managing and Implementing Training, Personnel and Human Factors Technology Within the Department of Defense." He indicated that, indeed, training is a "growth industry," with 6-7 billion dollars per year being spent on training within the Department of Defense. He suggested several critical problem areas which may be contributing to the technology/policy gap. Among them:

1. Poor documentation and lack of an audit trail concerning the research leading up to a policy decision point,
2. The need for better communication at the interface between researcher and user,
3. Little data concerning the cost of implementation, which translates into investment strategies and,
4. Lack of cost/benefit performance effectiveness data which is needed for justification of decisions made.

The solutions, naturally, follow from the problems. We must find ways to develop quantitative audit trails on our training research. A possible solution to the researcher/user communications gap is to co-locate research and development units with users in the field. Finally, we must develop and implement meaningful cost-benefit/performance effectiveness models for inclusion in our training research efforts.

EPILOGUE

It is this reporter's pious hope that he did no irreparable harm to the various speakers' notions through my possible (and more likely, probable) errors of omission and/or commission. The straightforward research oriented items are not too likely to have suffered in the process. It is this "fuzzy" area of policy that bothers me. Are HFS activities and government policy questions critically tied? In answer, I commend to your reading (as I recently did to the readers of the Computer Systems TIG Newsletter) Smoke Price's excellent article in the May HFS Newsletter: "The Budget Ax is Poised Again." While you are at it, look at the notice which appears in the June issue of the HFS Newsletter concerning an upcoming meeting of the AAAS committee on science and public policy. Also, the June issue of the APA Monitor has an excellent article on "Labor: Bridging Research and Policy." The point to be made is that there is a lot of concern these days about the problems involved in bridging this research to policy gap. The annual POC-HFS symposium attempted to tackle the area head-on and evaluate what we know about the process, as well as trying to look for solutions. I believe it is fair to say that, at the Chapter level anyway, we concluded we know damned little about the process and that we have precious few recommendations to make toward solutions. I propose, therefore, that a proper role for the Training Technical Interest

Group would be to sponsor a larger Training: Technology to Policy session at the next Annual HFS meeting. Let us evaluate, at the national level, what we know about or can contribute to this problem area. I think I can predict the outcome, but let's try anyway. Evaluation (especially of the self-evaluating variety) is the surest way to upset the tranquility of an organization!

KEYNOTE ADDRESS

"COMMUNICATIONS: THE KEY"

Dr. Robert L. Hilliard

Federal Communications Commission

When we probe beneath the technical terms of our specialized sub-areas of interest or when we take the time to look at the forest before we begin examining the trees, we realize that what we are really concerned with are the basic revolutions of the Twentieth Century: transportation, energy and communications. Their technological innovations have not only provided means of moving things through physical space, of creating the power for such movement, and of linking ideas and feelings among people as never before. They have permeated and affected every facet of life. There are few things--if anything--that you can think of that have not undergone political-social-economic-ethical changes because of the revolutions in transportation, energy and communications. A trite but still dramatic example: the automobile has done more than provide transportation; it has had as much effect on our mating and sexual behavior patterns as anything else in history. The same may be said for television's impact on nuclear family interrelationships.

In my opinion the most important of these revolutions has been communications. Communications in all its forms--from computers to television to satellites to lasers to electro-chemical brain waves to new varieties of person-to-person sensing and touching have had the most profound and powerful effects upon society.

That is what all of us--and, perhaps, particularly those of us whose personal interest and professional commitments bring us together as the Human Factors Society--are dealing with in one form or another every

day. All training technology--the subject of our conference here today--is communications. Every panel today, whether overtly deliberate or not, is oriented toward the need for effective communications.

Jim Baker (Army Research Institute), chairperson of this part of the conference, briefed me on what he thought I should cover in my remarks. He asked me to discuss how to get research results that will convince policy makers that our purposes are worthy of support; he asked me to tell how to present the results of that research so that they can be clearly understood by the policy makers; he asked me to explain how to analyze the system of political and legislative action so that we can successfully get research translated into implementation. He asked me to state how we can take the field of technology and make it one with policy.

And he asked me to do it in 15 minutes.

So I'm not even going to try to analyze the specifics of training, technology and policy. This presentation will try only to suggest some areas of concern that relate to the kinds of philosophy we sometimes discuss during these conferences over a glass of beer. And more often than not it seems that it is at such conference bullsessions that the most important philosophical comments are made and the most significant actions are taken.

Let us indulge, then, in a bit of jingoistic philosophy that we frequently are reluctant to proclaim at open formal sessions of a conference: Our Cause Is Just.

Just as the term "jingo" came from the British music hall, so does the concomitant echo of surprise come from the British stage: "ay, and there's the rub": if our cause is so just, why is it that we perpetually have so much trouble getting action on our findings and proposals?

Why isn't our research accepted for the great, significant, vital material so many of us believe--or, at least, proclaim--it is, and immediately implemented with appropriations and projects?

Some of our colleagues have suggested that we have failed thus far to figure out the technology-to-policy system. That many of the systems analysts among us have failed to clearly analyze the legislative and appropriations system that many more of us are dependent upon to bring feasibility into reality.

Is it possible that there really is no such system? Could it be that we have been searching for a continuum--analogical to linear communications--when in actuality only ad-hoc personal attitude and need decisions apply?

Is it possible that we have approached the problem from the wrong side entirely? That the system, as we would like it to be in order to enable us to get a clear handle on it, does not exist "in" there, but has to be created "out" here? Is it possible that the most effective way of affecting those who we have heretofore approached as being within a system that can be analyzed is to set up our own system to replace what may in reality be a non-system, so that those people will be

motivated to come to us to find answers to problems and needs that they have already perceived or that we may help them understand exist?

An example. The word "training" is in the title of this symposium's theme; let's for the moment equate the word "training" with the word "education." For some thirty years now research has clearly shown that television can be a highly effective means of enhancing the quality of learning on all levels. Yet, only about 2,000 of the nation's 20,000 school districts use television as a regular part of instruction. More significantly, in many places where television has been used it has been ineffective; it has been little more than another tool to achieve the same kinds of learning that have already been gotten through other, more traditional methods, thus not justifying its added requirements, facilities and expense.

That is because educational technology--educational communications--has by and large been superimposed on top of and into continuing educational systems that in many cases adhere to outmoded and irrelevant methods and processes of teaching and leaning, thus making it impossible for new technology to do much more than be absorbed by what is already dominant. It is as if we put automobiles on the roads without developing new highway systems or codes of traffic regulation, or as if we put broadcasting stations on the air without developing a system of frequency allocation. There would be--as there was before the basic transportation and communications approaches of the country were changed to accommodate

the new developments--chaos and/or exclusion of the new developments as effective growth forces.

Until we change the basic structure of education and training to accommodate and take fullest advantage of the new and continuing developments in communications technology, we shall go along using new, expensive hardware as bandaids at best, and in many cases as frills which, understandably, are the first to be cut by non-understanding and/or short-sighted school boards and administrators with tight educational budgets. Until the basic system (and process) of education as it largely exists today is changed, technology and television will neither be clearly understood nor supported as essential parts of that system.

Don't the same considerations apply to what we are concerned about here? If policy makers do not clearly and unequivocally see how the operating systems need our technology, why indeed should they give any priority to our research? If they do not see how our research findings fit into clearly defined needs of the systems, how can they--and why should they--wish to understand the implications of our research?

Some of us have called this situation an "alienation." We sometimes tend to regard the people "in there" as walled-in or walled-out from verities as we perceive them. And the more we believe an alienation exists, the more it becomes true. Is there really an alienation, or is it really a non-relating? (I see the latter as far less fixed or serious

than the former.) Is there a non-relating because the desired "system" has not been made clear?

Is at least part of the reason that the system has not been made clear the age-old problem of the specialists failing to adequately communicate with as well as to the generalists?

On the long list of technical areas that I know little or nothing about, computer-functioning has a pretty high priority. It is not surprising, therefore, that last year when I participated in a conference on computers and education I found myself "non-related" to and on the verge of "alienation" by a number of computer experts who continued to explain computers to me in terms of "bits" and "gates" while I was desirous--and principally capable--of talking about the effects of computers on learning processes, curricula and educational organization. I'm sure many of the computer experts thought I was stupid. I wasn't stupid. Only ignorant. But instead of talking with me in terms I could understand and of purposes that were most valid from my point of view, they continued to try to convince me in their language, not mine. And because there had not been established either a computer-based or rational-person-to-person existentialism in which I wished to fit, effective communication was minimal. They talked in technical factors. I wanted to talk in human factors.

Too many systems people do not know how to communicate except to themselves. Do you explain needs and potentials to policy

makers by giving them a multi-volume research thesis, or do you analyze their "human factors" and explain in terms meaningful to them? Like professionals in many other specialized areas, systems people sometimes tend to create cults--and the non-relating starts out here, not in there. Too many technocrats--including systems technologists--get caught up in a maze of technology and forget that they are dealing with human beings. And that humans are not machines. All of us are acquainted with some technologists, in fact, who believe it is blasphemous to suggest that humans are much better and more worthy than machines.

What is significant in terms of our needs at this immediate moment is that the solution to this problem most likely lies right here, with us, than anywhere else. The Human Factors Society is one of the few organizations that has the purpose, organization, wisdom and dedication to reorient society toward its real goals and purposes--of, by and for humans--and not machines.

We arrive, then, at two basic logistical considerations:

1. Presenting our research so that it is clearly understood by the policy makers and,
2. Understanding the well-defined needs of the policy makers' human systems, existing or those that we create for them.

Perhaps we have sometimes been proposing a jet plane to pull a cart? Maybe the cart has to be changed? Into a flying laboratory. Or maybe

it just needs to have some new wheels and floorboards and sides and should be pulled by a tractor? We clearly don't have all the answers and our field--as are we--is still evolving. We have to recognize that evolution is change and that the old traditional approaches for getting the support we need may not work. Consider for a moment the practical politics we read and hear about every day. Who are the most successful lobbyists? The ones who try to fit their product or service or idea into existing situations? Or the ones who develop and present a system in which their product or service or idea is clearly integral, essential and a prime-mover--one which the policy makers can see as beneficial to the country and to their individual goals and requirements and in which they realize it is necessary for them to participate.

The desirable system is out here, not in there. What have we to offer as a system? What can the Human Factors Society present which the policy makers will understand and support because they need to participate in it? Where can or should the Human Factors Society start, in order to clearly establish the need for technology to be translated into policy? In our agencies? In our companies? In our educational and training institutions? In our Society's organization? In our symposia? Shall we begin?

NOTES ON A SEQUENCE OF MODELS FROM RESEARCH THROUGH IMPLEMENTATION

Dr. John A. Modrick

Honeywell Inc.

The purpose of this paper is to present some ideas on a sequence of six stages or steps from research through incorporation of a technological development into the institutions of society. These ideas have grown out of thinking and discussion of transfer of technology in experimental psychology and human factors. Stated simply, the issue involved is how to get knowledge into the everyday institutional world in the form of things, procedures, and systems.

This paper has three objectives:

1. Outline a sequence of stages from research through implementation
2. Describe each stage in the sequence
3. Discuss some implications for human factors and psychology as well as the processes of bridging the gap between research and public policy.

Illustrations will be drawn from the area of learning and training; however, the ideas are equally applicable to other areas.

The approach taken to this topic is the viewpoint of an experimental psychologist with conventional training and experience in research and teaching. However, this viewpoint has been broadened, shaped, and contaminated by several years of applied or technological work in government and industry. I have not explicitly consulted bibliographic sources or done a literature search, although it is probable that someone has written relevant articles. The immediate source of the ideas expressed here is a reflection on the activities within my own organization in defining and shaping our role in a major industrial, technological organization.

We in human factors should be concerned with the sequence from research to implementation because there is a pronounced trend of accountability in the funding of research and development. This accountability seems to be defined in terms of the implementation of research findings into some "things" of social benefit. We need to think of the validation of our research programs in terms of their potential instrumentality for achieving social goals. At the same time, we need to manage the process of technology transfer in such a manner that the researcher has some insulation from the day-to-day demands of the real world and enough freedom of action to support the creative process. I suggest that we in human factors have, at a minimum, a responsibility to participate in the process of translating our knowledge and technology into applications for the solution of social problems and the satisfaction of social needs. It is neither to our interest nor to that of society that we detach ourselves from that responsibility and leave it to "someone else."

SIX STAGE PROCESS OF THE TECHNOLOGICAL CYCLE

A six-stage process is proposed. The stages are grouped under three headings of Development, Feasibility, and Institutionalization:

Development:	Generating knowledge and solutions of problems. It consists of the stages of research and technology.
Feasibility:	Trying and evaluating proposed applications. It consists of the stages of application and utilization.
Institutionalization:	Defining procedures and policies for using a technological development. It consists of the stages of implementation and deployment.

The relationship between these six stages is shown in Figure 1.

This process is driven by social need which has its primary input to research and secondary input to the other stages as a guiding, goal-directing influence. Social benefit is an output at the other end of the cycle. Each of these stages has different objectives, processes, methods, and informational requirements. They are, however, serially dependent.

It is conceded immediately that this paradigm is an oversimplification. For example, an invariant one-way flow from research to institutionalization is assumed. Feedback, feed-forward and iterative loops can be added to reflect the real complexity of the process. Any stage can generate or modify the social need. Social benefits may fall out at any stage as by-products.

This simplification is intentional from the purpose of defining a nominal or baseline process and *focusing on the characteristics* of the stages unencumbered by details.

RESEARCH

Research is the generation of a body of knowledge. No differentiation is made between basic and applied research for the present discussion. The factors defining this stage are summarized in Table 1.

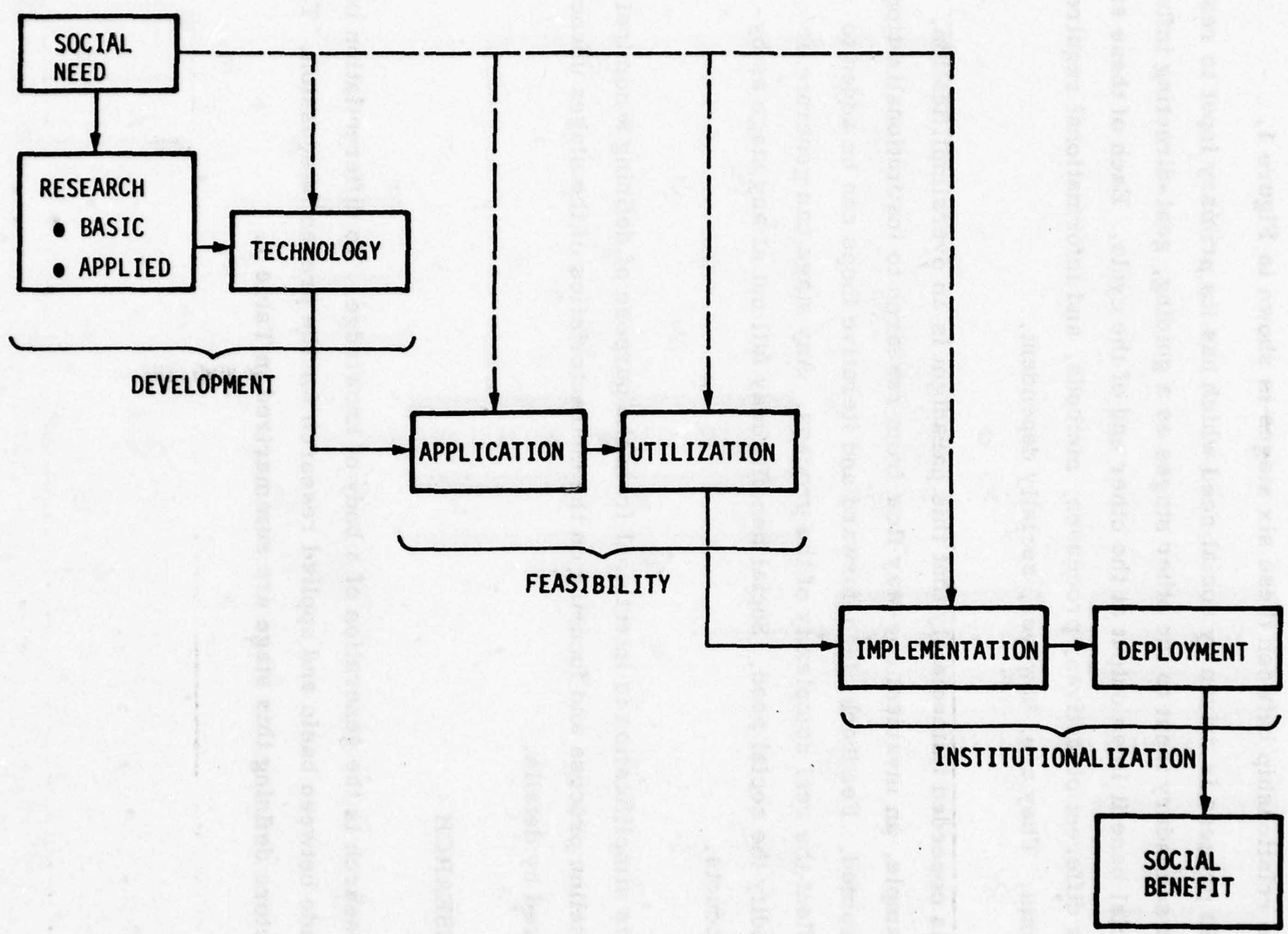

Figure 1. Six-Stage Process of the Technological Cycle

Table 1. Factors in the Stage of Research

Objectives
• Establishment of functional relationships
• Description of processes
• Identification of variables
Distinguishing Characteristics
• State of the art not relevant
• Hypothesis testing
• Directed by internal criteria

The establishment of functional relationships between variables is an overriding objective building on the identification of variables and the description of processes. It was a surprising insight to realize that the state of the art is not a relevant criterion for evaluating research; the major criterion is contribution to the body of knowledge. Other criteria, internal to the research process itself, deal with such considerations as standards for quality of data, adequacy of control of variables, and heuristic value. Research proceeds by a process of hypothesis testing and rejection for the purpose of selecting among alternative theoretical explanation of phenomena.

Studies of the learning process leading to principles of learning are illustration of this stage. Investigations of programmed instruction and the use of computers for education or training are on the borderline between research and technology; they are evaluated in part against criteria of solution of a

practical world problem. The generation of knowledge is involved in these applications; techniques are developed and in some instances more research is initiated to generate additional knowledge. However, these activities are done in the service of making something work. When one goes further and writes programmed or computer-controlled lessons for instruction, one is clearly no longer in research.

TECHNOLOGY

Technology is the directed application of knowledge to solve a class of problems. The underlying question behind technology is whether we know enough to put together a workable solution to real-world problems. The properties of technology are summarized in Table 2.

Table 2. Properties in the Technology Stage

Objectives:

- State-of-the-art methodology
- Process models
- Techniques

Demonstration of Applicability

- Breadboard mockups
- Subsystem working models

Social and Institutional Factors

- Management factors
- Economic factors
- Sociological factors
- Political factors

Technology is directed to a class of problems rather than the solution of any one specific problem. Applicability is demonstrated by developing partial models or mockups for one or a small number of representative situations. The state of the art is the primary criterion for evaluating technology; one must demonstrate that the available knowledge, process models, and techniques are adequate to define and implement a solution.

For example, when programmed instruction was an instructional technique emerging from research on the learning processes, there was a period during which illustrative programmed texts and computer-controlled lessons were written. The purpose in writing them was to demonstrate that the proposed solution was in fact workable on small scale and that further development was warranted. Typically, initial demonstrations at this stage are inefficient and cumbersome; they become more efficient and elegant with experience.

It is at this stage of technology that social and institutional factors first become a relevant consideration. The fears of displacement of teachers during the early exploration of computer-aided instruction is an example of a sociological factor; the comparative hourly cost of instruction for conventional and computer-based training is an economic factor. Many an educational administrator has undoubtedly thought about the implications for management of his school system. Since programmed instruction offers the potential for individualized pacing of learning, completion time is not a fixed value, such as 16 weeks, but a distribution of times. Therefore, some students finish a course in two weeks while others take six months. Under this condition, it becomes very complicated to keep track of support

needs, resource utilization, and the status of students. These factors are considerations that must be dealt with if programmed instruction is to be incorporated within the educational institutions.

Political factors include a mixture of social and personal issues. Primary among them is how one justifies putting resources into that application. The school board has to be sold the idea. Support entails a consideration of social priorities. An educational administrator has to consider the career and personal implication from a comparison, for example, of supervising fifty teachers versus five teachers and a computer. Who ever got a raise for supervising a computer?

APPLICATION

Application is the use of technology to solve a *specific problem* rather than to solve a class of problems. The nature of application is summarized in Table 3.

Application is the stage at which the total system is first dealt with. For example, computer-based instruction might be used to teach a whole course. It is the extension of the partial demonstrations from technology to the full scale application of a real-world problem.

A detailed analysis should be done to specify the functional capabilities required to satisfy the need. In addition, parameters and constraints specific to the situation must be determined. The breadboards, mockups, and models developed under technology are expanded according to a conceptual design and integrated into a functioning system. Evaluation is done

Table 3. Characteristics of the Application Stage

Definition of Problem
• Need
• Functional requirement
• Specific situational parameters and constraints
Design of Solution
• Conceptual design
• System integration
Evaluation
• Field studies
• Demonstration of feasibility
• Cost-gain analysis
• Identification of operating problems

by means of field studies with an emphasis on feasibility, cost-gain analysis, and identification of operating problems.

The early developmental work on PLATO and TICCIT are of this sort. The feasibility studies of closed circuit television for instruction also illustrate this stage. If the results of these full-scale tryouts are positive, the process moves on to the next phase.

UTILIZATION

Utilization consists of constructing, operating, and evaluating a prototype system. "Let's see if this thing will work in the real world under the tough conditions and the complexity of an operational environment--out of the laboratory." The types of factors involved are summarized in Table 4.

Table 4. Factors in the Utilization Stage

Build

- Engineering or System Specification
- Construction

Operation and Support

- Operational and organizational concept
- Procedures
- Personnel requirements
- User characteristics

Allocation of Resources

- Schedule
- Support
- Cost

Management

- Administrative support
- Control
- Accountability

Assessment

- Evaluation
- Benefits
- Problems

These factors run the gamut from build and install through operation to assessment. The status of PLATO and TICCIT illustrate this stage in instructional technology. The scope and complexity expand greatly at this stage. Few precedents and models exist for this stage; it is perhaps seldom done explicitly. The armed forces may have the best existing procedures for accomplishing this phase.

An important consideration in utilization is the operational and organizational concept. It consists of the definition of such operational factors as who "owns" the system, how it operates, how it is supported, and who is accountable for it. These factors are important if a new development is to become an integral part of the institutional social system. Currently existing computer-aided instructional systems, for example, are typically not integral to a school because there is no operational and organizational concept and such systems do not fit into the current system. They occupy a separate room apart from the main flow of activity. Pet educational toys of local champions, these systems are used as prestige showpieces of the school system. They can be counted on as a stimulus for an occasional newspaper article. If the development of computer-aided instruction stops here, it will atrophy from a lack of organizational support and stimulus.

IMPLEMENTATION

Implementation consists of incorporating a technological development into the institutional structure of society. Representative elements of this stage are summarized in Table 5.

Table 5. Representative Factors of the Implementation Stage

Socio-Economic Assessment
• Responsiveness to social need
• Social priority
• Profit
• Life cycle cost
• Social problems
Feasibility
• Adequacy of state of the art
• Scope of application
• Support requirements
• Institutional compatibility
• User acceptance
• Cost-effectiveness tradeoffs
Management
• Organizational responsibility
• Policy formulation
• Schedule
• Authorizing legislation or documentation
• Safeguards
Resource Allocation
• Fiscal support
• Personnel
• Facilities
• Accounting procedures
• Funding authorization

The scope of this stage is regional or national policy. Authorizing and controlling legislation become relevant. Social priorities in support and funding become critical issues. Apparently, these matters are dealt with most often today by the federal legislature, federal executives, and lobbyists. Some of the factors are political and require the generation of adequate political support. For example, institutional compatibility concerns how well the new development fits into the existing system. User acceptance addresses the question of whether the current incumbents of relevant positions will cheer or raise a furor. Authorizing legislation or documentation and fiscal support require actions of public policy. A purchase order or personnel action require authorizing citations. Cost-effectiveness tradeoffs refer to the often cited objective of "more bang for the buck."

DEPLOYMENT

Deployment is the final stage. It consists of production and distribution in accordance with demand. At this stage the technological development cycle is completed.

IMPLICATIONS

I will be brief about the implications. In truth, I have given them relatively little thought.

First, I am impressed by the complexity of the process. Further, I have some apprehension about our ability to make this complexity tractable to our needs.

Second, our interest drops off markedly after technology. We also appear to have very limited, formal or systematic methodology beyond that point.

Third, there is a marked *discontinuity between research and implementation*. Researchers tend to know little and care less about implementation and have little apparent aptitude or tolerance for it; implementors know little and care less about research and have little apparent aptitude or tolerance for it. They are two different kinds of people. The implication is that requirements and knowledge are not transmitted; a multiplicity of wheels are continually reinvented. Old problems, issues, and needs are always seen as new with no related resources on which to draw. Continuity and utilization of knowledge are matters of personal initiative.

Fourth, a mechanism for interdisciplinary communication is needed. However, it is not clear what the related disciplines are. Human factors itself is a polyglot mixture of disciplines. Engineering is involved but it is not homogeneous. The users cut across the entire spectrum of society; in education and training alone they are teachers, educational administrators and students. Public administrators, politicians and lobbyists are also involved. Speaking only for myself, these are strange bedfellows indeed.

Policy makers and people who enact and implement laws are a category of people with whom I have little interaction, as do my colleagues and associates. I recently heard a brief description of the typical federal policy maker: "He is a middle-aged lawyer who was in World War II. He dislikes long hair and people who smoke pot. He is an elected official, political appointee or lobbyist."

Fifth, there are some serious implications for professional education, especially in human factors. We train either basic scientists or engineers. We do not train technology translators. Some people move into policy formulation and implementation but seldom as an intentional career choice. I suspect that such decisions are made as a way out of "dead-ended" jobs and without appropriate preparation or training. To expect a high level of competence puts a burden on on-the-job training that exceeds reasonableness.

Over the past twenty-five years we have become increasingly aware of the interprofessional ties involved in human factors. I have recently begun to think that we are becoming aware of another interprofessional commitment. When psychologists first began to apply experimental psychology to the design of man-machine systems, we implicitly accepted a latent responsibility. That responsibility is to participate in managing the processes of applying knowledge. We need to broaden our thinking about the profession to insure that we provide adequately for this role.

As I was finishing my preparation I read a popular, critical article on educational innovation by Walter S. Minot entitled "Educational Quackery Would Disappear If..." (National Observer, week ending May 29, 1976, p. 20). A sentence in that article captured some of my feeling about the importance of the topic of this paper and program. It was: "Then it would merely make an already disastrous situation worse than simple, unpracticed human incompetence can achieve by itself."

Let us not let that disastrous situation happen.

ORGANIZATIONAL ANALYSIS:

A NECESSARY COMPONENT FOR DEVELOPMENT

& EVALUATION OF TRAINING PROGRAMS

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INTRODUCTION

While the purpose of this paper is to discuss the role of organizational analysis, it is important to begin by mentioning two guiding principles which should govern all training activities.

1. The development of the instructional technique and the evaluation model must be based upon careful and thorough need assessment of the organization including task, person and organizational analysis.
2. The systematic development of any training or change technique is dependent upon thoughtful evaluation which provides the information necessary to suggest revisions in our techniques.

An appropriate name for these two principles could be the sacred two! While most individuals concerned with training systems agree to the importance of these points, the basic literature including journal articles as well as technical reports indicates that our concern is mainly reflected by lip service.

NEED ASSESSMENT

Instead of careful need assessment, our field appears dominated by a fads approach. Children go from hoola hoops to skate boards and we move from sensitivity training to organizational development to

computer assisted instruction. Probably, each of these techniques has a place (for the children also) but we never seem to find out very much about our approach before we are off examining another type of program. This type of fads approach places a heavy emphasis on the development of techniques without consideration of needs assessment followed by a matching of the technique to the needs. It is interesting to note that machinists don't choose their tools before examining the job and a gardener usually chooses a sprinkling system rather than a bucket to water a half acre lawn. Yet, we still have to be warned by quotes like the following:

> "If you don/t have a gadget called a teaching machine, don't get one. Don't buy one; don't borrow one; don't steal one. If you have such a gadget, get rid of it. Don't give it away, for someone else *might* use it. This is a most practical rule, based on empirical facts from considerable observation. If you begin with a device of any kind, you will try to develop the teaching program to fit that device."
>
> (Gilbert, 1961, p. 478)

Gilbert is not saying that teaching machines or sensitivity training or CAI or any other technique doesn't work. He is saying that the design of change programs don't begin with instructional media. Instead, we must, through need assessment, determine the objectives of our programs so that our criteria for evaluation and the choice of instructional program are made realistically.

There are dozens of studies that can be cited which demonstrate the dangers of designing training programs without needs assessment. Perhaps, one of the sadder examples is shown in an investigation (Miller & Zeller, 1967) of 418 hard core unemployed trainees in a program to train highway construction machinery operators. The authors were able to obtain information from 270 graduates. Of this group, 61% of the graduates were employed and 39% unemployed at the time of the interview. In addition, more than half of the employed group said they were without jobs more than 60% of the time. Some of the reasons for the unemployment situation were inadequacies in training which included not enough task practice, and insufficient training time. The details showed that the program was not based upon a consideration of the job components. One trainee noted that "the contractors laughed when I showed them my training diploma and said 'come back after you get some schooling, buddy.'"(p. 32-33). In a familiar lament, the authors of the report wonder how a training program could be designed without a thorough analysis of the skills required.

EVALUATION

The second component of the principles is the evaluation process. Evaluation is an information gathering process that cannot possibly result in decisions of totally good or totally poor programs. Instructional programs are never complete but instead are designed to

be revised on the basis of information obtained from evaluations that examine relevant multiple criteria. Unfortunately, the feedback process that could result from effectively designed evaluations has been more likely to conclude in emotional reactions rather than decisions to use the information to improve the program. Evaluation must be treated as one part of a long term systematic approach.

The better experimental procedures control more variables permitting a greater degree of confidence in specifying program effects. While the constraints of the environment may make laboratory type evaluation impossible to achieve, an awareness of the important factors in experimental design makes it possible to avoid a useless evaluation. Certainly, the real world has many constraints and these limitations effect the designs employed. Thus, a pure do-nothing control group is not always useful in the examination of instructional programs. We would not be interested in being flown across the Atlantic Ocean in a 747 jet plane by a pilot who was randomly placed in the uninstructed control group. However, there are many instances where controls consisting of the old technique or on-the-job training as compared to the institution of a new type of program are appropriate. The job of the analyst is to choose the most rigorous design possible and to be aware of its limitations. Unfortunately, there are few studies that employ the most rigorous design within the limitations imposed by the environment. In many instances, the authors of research articles apologize in advance

for poor designs which obviously could have been strengthened by some initial effort. It appears that most efforts at evaluation are afterthoughts. While I would not wish to suggest that the employment of experimental designs is a simple procedure, a degree of planning and the use of elementary procedures would significantly increase information gathered by our techniques.

The interrelationship of need assessment, program development and evaluation can be examined in Figure 1. This model indicates that both the development of the training program and the criteria chosen to evaluate the consequences of the training program stem directly from the need assessment. While it is tempting to devote the rest of this paper to a discussion of the interrelationships of all of the components of this model, that material can be found elsewhere (Goldstein, 1974). Instead the purpose of this paper is to discuss one particular aspect of need assessment, organizational analysis, which has not received the attention it deserves.

ORGANIZATIONAL ANALYSIS

Organizational analysis refers to an examination of the system wide components of the organization that affect the training program beyond those factors which are ordinarily considered in task and person analysis. It includes an examination of: the organizational goals; the resources of the organization; and the internal and external constraints present in the environment. This author has become convinced that many training programs are judged as failures because of organizational system

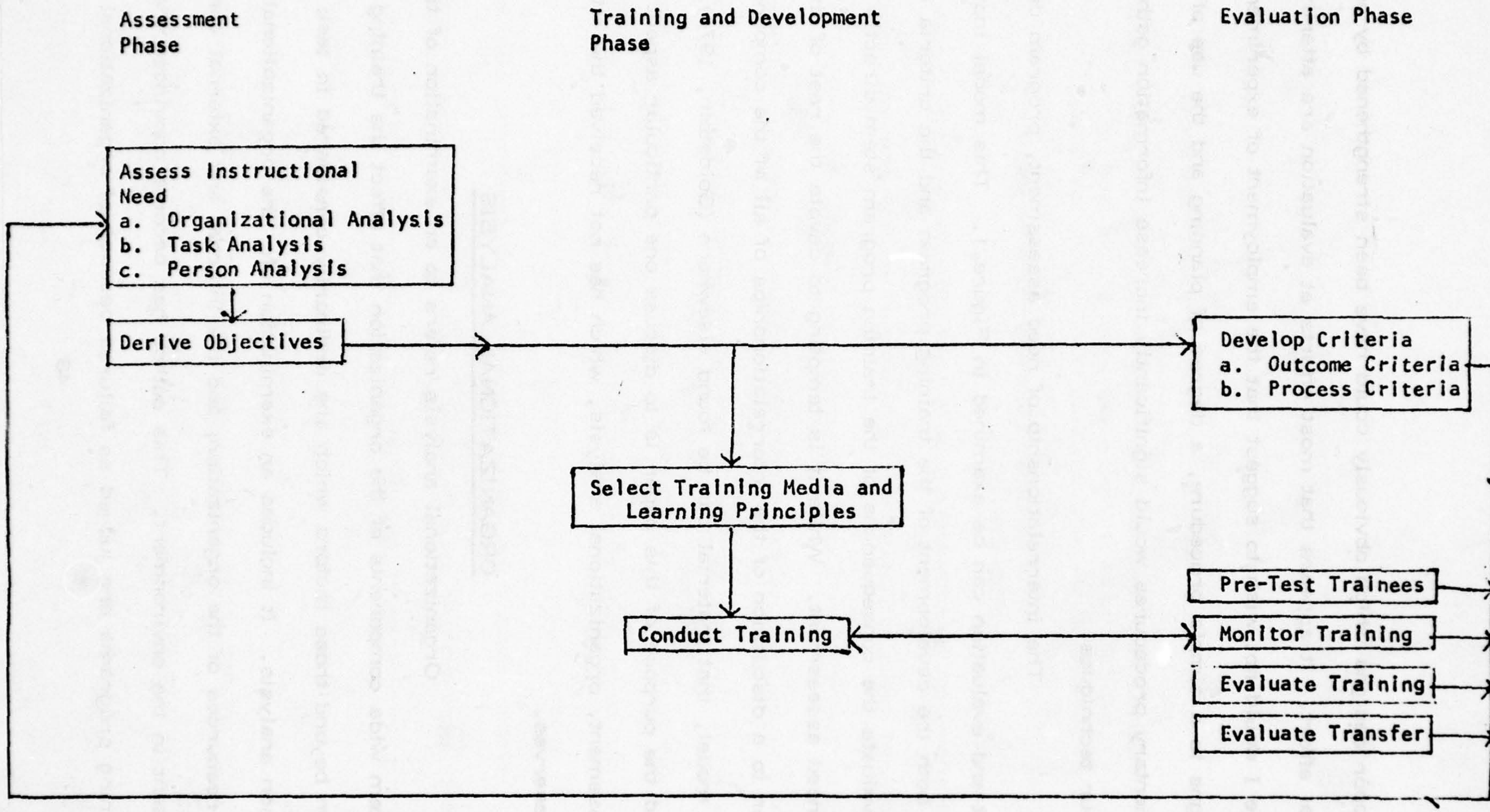

Figure 1. An Instructional System Adapted From Goldstein, I.L. __Training: Program Development and Evaluation__. Monterey, Calif. Brooks/Cole, 1974.

constraints. If this is true, the solution to this difficulty is to make certain that organizational analysis is included as part of the need assessment process. In that way, these factors are considered both in the design and evaluation of the instructional program. If indeed, this aspect of need assessment is so important, the author of such an idea should be able to specify what some of the problems are that effect our programs with such detrimental consequences. Therefore, the next section will examine particular problems which occur because the training community has not utilized organizational analysis along with its more time honored techniques of task and person analysis.

The Problems of Unspecified Goals

When organizational goals are not considered in the implementation of training programs, objectives and criteria (see Figure 1) which ensue from the need assessment process are not appraised. Later the organizations are not able to specify their achievements because they have not collected the necessary criterion information. Beginning in the 1960's, the federal government instituted programs like Project Headstart, Title 1, and Project Follow-Through. They are social action programs directed at millions of children, created by Congress and administered by federal agencies. While most investigations concentrated upon pupil achievement as the criteria for success, some analysts (Cohen, 1970) noted that the original Congressional Act had many goals including the

reduction of per-pupil expenditure between the cities and their suburbs. The purpose here was

> ". . . to deliver more resources to the poor, whether they are districts, schools, children or states. It is, therefore, essential to know how much more and for whom. It is important because citizens should know the extent to which official intentions have been realized, and because without much knowledge on that score it is hard to decide what more should be done."
> (p. 222-223)

When these data are not collected, it is not possible to determine the success of the program or to answer all the questions posed by sponsors. Many problems fail because organizational objectives were not included in the design of the instructional program. This writer has seen students withdrawn from computer-assisted instructional programs in some school systems because the parents were uncomfortable when they realized that Johnny and Jane were not sitting and listening to lectures as the parents had done when they were school children. If the organizational objective was to gain acceptance of a new media in an instructional system, then the training program should have included this as an objective. Perhaps, the results of this objective would have been an orientation program for the parents.

The problems of unspecified goals are almost numerous enough to take up the remaining space allotted to this paper. For example, Lynton and Pareek (1967) have described a program that

successfully results in training foreign born engineers in American universities. However, the failure to specify the organizational objective and its consequences resulted in a program that did not meet the needs of the original country. In this case, an organizational objective was to have the trained engineer return home. Any examination of that objective would have shown the program to be unrealistic because the training qualified the individuals for jobs that simply did not exist in the native environment. Similarily, most training programs are based upon skill requirements and typically ignore organizational objectives especially when the objectives are unspecified. Yet, the organization often judges the value of the program on the basis of their own objectives which were never specified, never considered in the design of the program and never utilized in designing the evaluation model. Thus, the cost of many instructional programs result in their early demise even though the instructional system may be meeting the performance requirements. Similarily, organizations might expect training programs to provide trainees with expectations about the job or particular views toward performance requirements. It is not unusual to discover that some police training programs are devoted to skill requirements (e.g. operating a police vehicle or utilizing firearms) or information requirements (knowing the difference between a felony and misdemeanor). Yet, organizational analyses often discover that there

are other organizational expectations concerning interpersonal relationships with the public and a concern for all citizens regardless of race, color or creed. Unfortunately, when these organizational philosophies and emphases are not clearly defined and specified, they don't enter into the training program and are often given short notice in the instructional sequence. Adding to this problem is that it is a lot easier to teach weapons procedure than to instruct in the topic of interpersonal relations. Thus, certain topics are de-emphasized and sometimes police departments only become aware of this problem when facing a series of complaints from various community organizations. At that point in time, everyone wonders why the organizational objectives were not translated into training and job requirements.

The Problems of Organizational Conflicts

In some instances, there are organizational dynamics that affect training programs which can not be simply described as unspecified goals. The most insidious of these types of problems are organizational conflicts that somehow (with a magic wand) the training program is supposed to resolve. More likely, the training program becomes an astounding failure. A good illustration of these problems is offered in a training program designed by Fleishman, Harris, and Burtt (1955) to produce more considerate foremen. At the end of the program, the foremen had become more considerate than a comparable control group. At a later time, these investigators collected further data on the job

which indicated that the changes were not maintained. An investigation determined that the supervisors of the trainees were not supportive of these new behavior patterns. Thus, the foremen reverted back to their old behavior. Some analysts use these data as support for the adage that training should start at the top. I prefer to think that there was a conflict between the goals of the organization and the training program which must be discovered before training begins. In instances marked by conflict, complete success in training could still result in a program that failed. It is also likely that in programs that are not as well analyzed as this study that few would realize the training program didn't work.

The history of training programs for the hard core unemployed (H.C.U.) reflects similar problems. First, many programs have failed to specify organizational objectives that go far beyond the components of work ordinarily stemming from job analysis. Miller and Zeller state the problem this way: "It might have been helpful to have included within the training experience itself practice in job hunting, assistance in contacting employers before the end of training, and following-up counseling and job-placement help." (p. 31) The themes of job placement, counseling and attention to the needs of the trainee appear in most programs that have evidence of success. In some cases, the attention is manifested by health care for individuals who previously

were not able to attend training because of their ills. In other cases, the consideration is careful transportation directions because the trainees cannot find their way to the training or job site. It appears that training programs cannot just attend to job skills but must also consider the trainee as an individual within a social system. In many instances, the trainee not only lacks job skills but also is not knowledgeable about many aspects of being a worker, e.g. health care, transportation, baby sitters, promptness on the job, etc. These factors make careful organizational analysis and need assessment procedures mandatory. As complex as the determination of these organizational objectives appear to be, the determination of the objectives by themselves will not do the job. Unfortunately, many of these situations are also marked by organizational conflicts which are very disruptive. For example, conflicts between the government sponsors of the program, the employers and the training institutions can completely disrupt the program (Goodman, 1969). Many of these conflicts are based upon different goals and expectations. Thus, the community training organizations might see their role as introducing people into the world of work while the employer is concerned with obtaining and retraining people at a minimum cost. When these conflicts remain unresolved, we have a situation with conflicting goals and objectives which eventually undermines the potential success for the HCU.

The temptation for the training analyst in these types of situations is to ignore the conflict and hope it will go away. However, conflicts don't usually go away; they usually become more serious. Also, the training program is blamed for the failure. The only solution is to do the organizational analyses, determine the conflicts and resolve the issues. Thus, part of the need assessment process is the clarification of the objectives upon which the program will be developed and evaluated. As we have learned from our emphasis on systems approaches to organizations, there are many interacting forces. The solution to many of these types of problems are not training programs but rather procedures which must first be used to resolve the organizational conflicts.

The Problems of Organizational Constraints

Most of the emphasis has been on organizational analysis which has as its primary goal the development of information necessary to design and evaluate an instructional program. In the preceeding section, there was some indication that other parts of the organizational system partially determine the success of the training program. The problem to be treated in this section is our failure to recognize the importance of all the interacting components of an organization and its effects upon our training programs.

The best illustration of these organizational constraints is the relatively recent impact of fair employment legislation. Sheridan

(1975) describes with pointed clarity, the AT & T attempt to comply with a government order to place 19% females in outside craft jobs. Despite regorous recruiting and training efforts, the women they did manage to recruit into the job dropped from training at an average rate of 50%. The individuals who completed training usually didn't last a full year. Their analysis determined that the physical differences between men and women made the job extremely difficult to perform. Some of the most serious problems centered upon the use of the ladder which is quite long and heavy. Utilizing the basis principles of human factors, the job was redesigned so that it could be performed by women.

There are several major aspects of this illustration which are relevant to this paper. First, there are many constraints which affect our training programs which must be considered in the design and evaluation phase. In this case, the constraint was fair employment legislation which resulted in different types of individuals entering the instructional program. In other cases, the constraint might be a technological change which will result in new goals, new types of trainees or new jobs. In yet another case, it might be new federal or state safety or environmental requirements which affect the objectives of our programs.

Another aspect of the AT & T example which is worth noting is that the solution was not in the design of the training program

but rather the redesign of the job. Organizational analysis must examine all of the relevant components of the organization from the entry level selection system to the reward and promotional policies. The design of promotional training programs is often very dependent upon the entry level selection system which in turn determines the basic skill levels of entering employees. Too many of us have designed supervisory training programs for individuals that don't exist because the initial selection program is designed only to consider individuals who can perform the entry level job.

A FINAL COMMENT

There is no reason to pretend that organizational analysis will solve all of your training problems. Indeed, it is only one component of the instructional process. The point being emphasized in this paper is that organizational analysis is an important aspect which has been neglected. In part, the problem is that we have not worked out the procedures to perform organizational analysis with the same specificity that we have worked on task analysis. I suspect that many of the same techniques ranging from interviews, to questionnaires to critical incident methods will prove as useful in organizational analysis as they have in task analysis. More than likely, the differences will be in the types of questions that we ask and the positions of the individuals to whom the questions are addressed. Organizational analysis starts at the top of the organization and is concerned with issues like organization goals, resources, constraints, conflicts, etc. The process will not be easy but I suspect it will pay a rich dividend.

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RESEARCH FUNDAMENTAL TO TRAINING OF PERSONNEL FOR SHIPBOARD WORK

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Work on a ship is varied and takes many forms. The most salient aspect of shipboard work to anyone who has ever spent any time on a ship, however, is its technological complexity. The environment on a ship involves a great deal of complex equipment and systems; a great deal of the work on a ship is concerned with operating and maintaining such equipment. People must be trained to perform that operation and maintenance.

If one contemplates how to set up a program of research fundamental to training personnel for shipboard work, or fundamental to any operational Navy problem, I suspect, one cannot help but be impressed with the need for the scientific officer, the person who runs such a program, to keep one hand in the world of the Navy and its concerns and the other in the world of science, the zeitgeist of the scientific discipline involved. (See Figure 1)

The concerns of the Navy in this instance are clear. We need to train personnel to operate and maintain the equipments found aboard ship. In these days of shrinking operational budgets, we must train them as quickly, efficiently and cheaply as possible.

The scientific zeitgeist is that of cognitive psychology, the psychology of the activities of processing information, remembering, thinking, solving problems. I won't dwell on this point. In other forums I have outlined the factors that impelled us into a renewed interest in

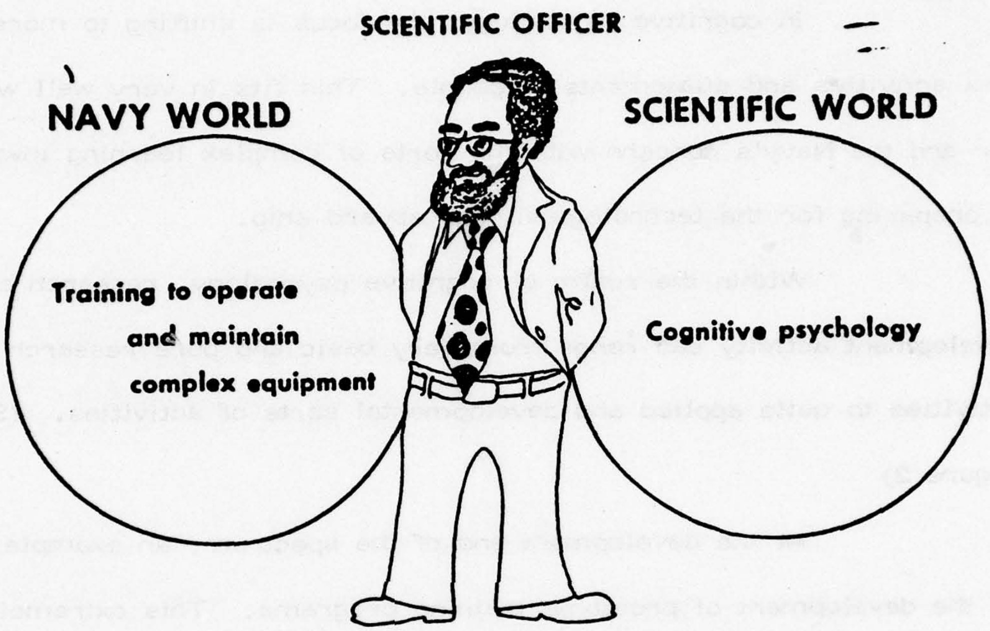

SCIENTIFIC OFFICER
NAVY WORLD
SCIENTIFIC WORLD
Training to operate
and maintain
complex equipment
Cognitive psychology

FIGURE 1

cognitive psychology, and have spoken about one specific focus of that renewed interest, namely Individual Differences in Cognitive Processing.

In cognitive psychology, the focus is shifting to more complex activities and attainments of people. This fits in very well with our and the Navy's concern with the sorts of complex learning involved in preparing for the technological jobs aboard ship.

Within the realm of cognitive psychology, research and development activity can range from very basic and pure research activities to quite applied and developmental sorts of activities. (See Figure 2)

At the development end of the spectrum, an example might be the development of prototype training programs. This extremely important activity is carried on in the Navy by agencies, such as the Navy Personnel Research & Development Center, concerned with 6.2 and 6.3 development activities. It is not properly a part of the ONR Personnel & Training 6.1 research charter.

At the "pure" research end of the spectrum there is, for example, fascinating work on the neural correlates of cognitive activity. This forward-looking work, while basic in nature, is too far removed from its point of possible utility for ONR Personnel & Training Research Programs' interest. It is properly supported by organizations such as the National

RESEARCH & DEVELOPMENT IN COGNITIVE PSYCHOLOGY

'PURE' RESEARCH	Neural correlates
MISSION-ORIENTED RESEARCH	Cognitive psychology in an instructional context
DEVELOPMENT	Prototype training programs

FIGURE 2

Science Foundation, the National Institutes of Health, and the National Institute of Mental Health.

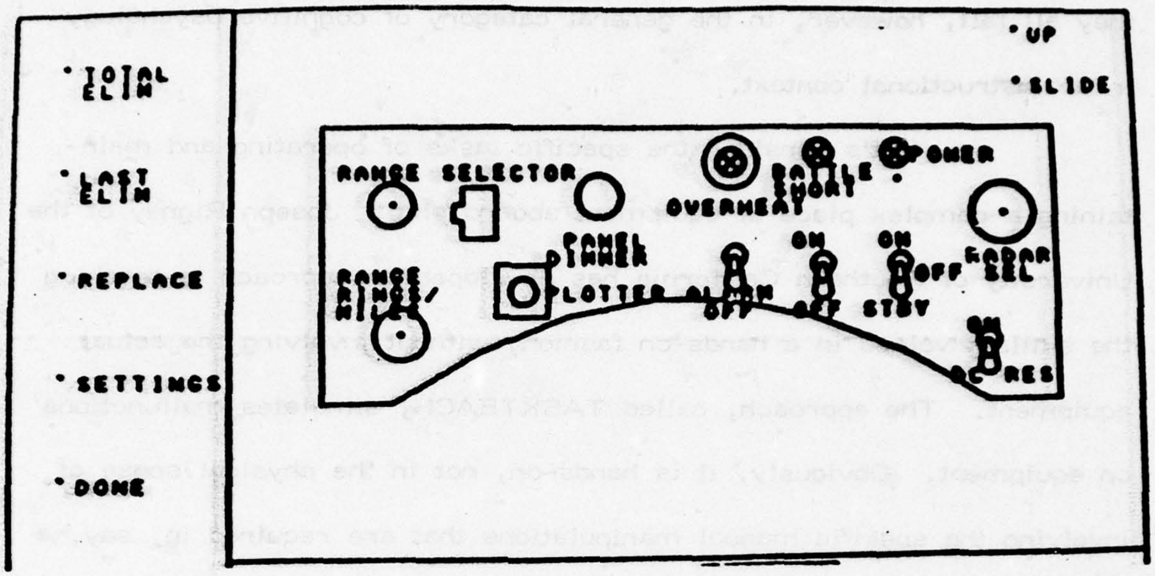
The 6.1 research interest of the Personnel & Training Research Programs lies at an intermediate level on this scale. We are concerned with research that is clearly basic and general in nature, but has an apparent direct, but not immediate, relation to Navy needs, to training people for shipboard work. The particular aspect of our research interest I'm going to emphasize today is our study of cognitive psychology in an instructional context. Our total effort in cognitive psychology comprises nine work units, which, with some ARPA financial participation, cost about $850,000 a year. The four work units of which I'm going to talk about selected aspects, consume just under half of those resources.

In the work I'll talk about, the emphasis is on the behavioral study of cognitive processes in the context of instruction, where instructional experimentation serves to give us a fundamental theoretical understanding of basic cognitive activities, thinking, information processing, remembering, problem solving. The things we study, we hope, will have broad generality across domains; the eventual instructional applicability will be broader than the specific subject matters being studied. The examples I'll speak of briefly use different subject matters as vehicles for study, and they focus on different cognitive processes;

they all fall, however, in the general category of cognitive psychology in an instructional context.

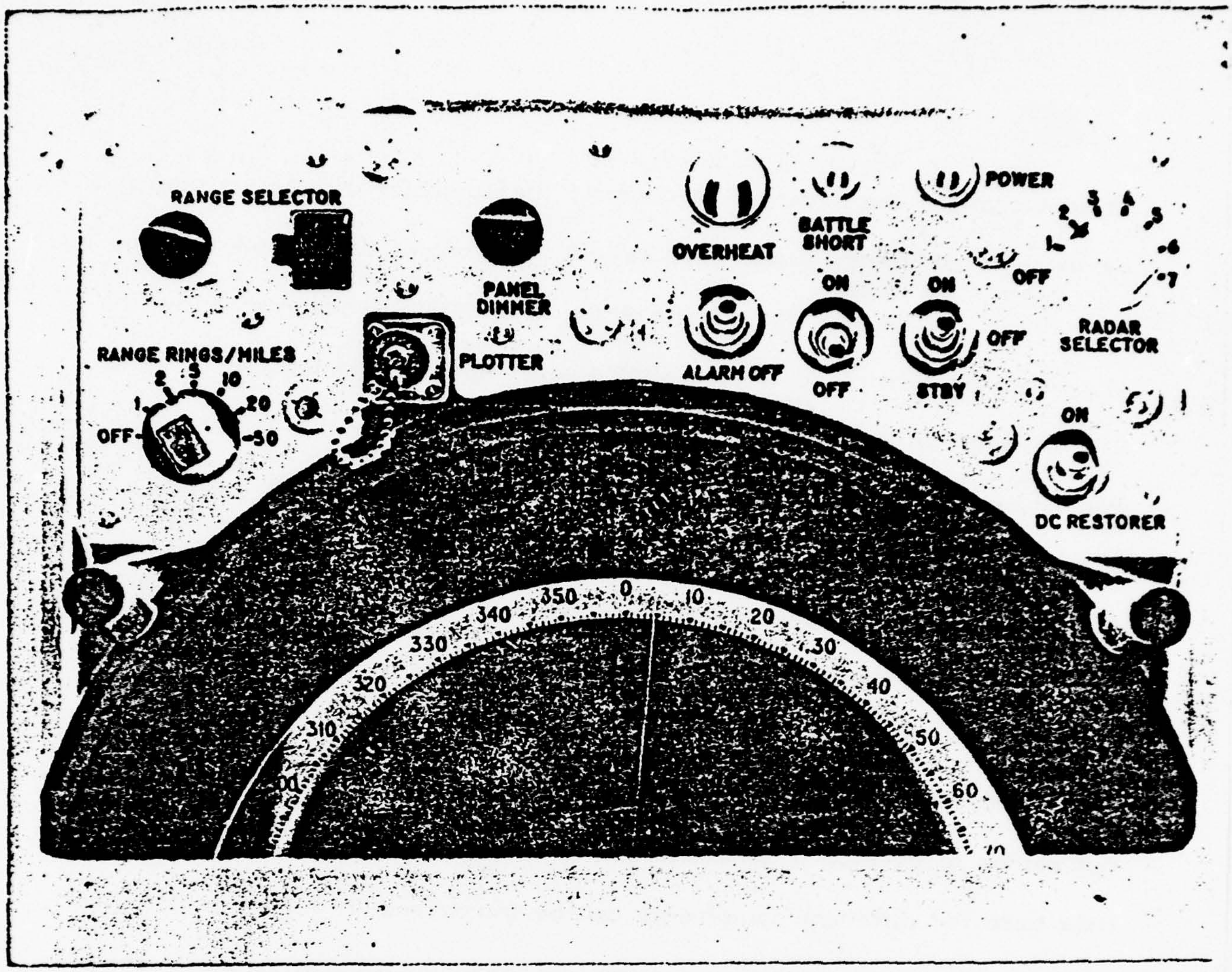
Let's consider the specific tasks of operating and maintaining a complex piece of equipment aboard ship. Joseph Rigney of the University of Southern California has developed an approach to teaching the skills involved in a hands-on fashion, without involving the actual equipment. The approach, called TASKTEACH, simulates malfunctions on equipment. Obviously, it is hands-on, not in the physical sense of involving the specific manual manipulations that are required in, say, a particular fault-finding activity, but in a cognitive sense, involving the decisions and reasoning that would have to be made in the real situations.

Let's illustrate the approach in a concrete instance. Figure 3 gives the computer graphics depiction of a part of a SPA-66 Radar Repeater, an equipment still in use. The student can interact with this display, using a light pen. He can, for instance, touch the dot next to the work "slide" and get to see a slide (Figure 4) of the corresponding part of the actual front panel. By touching appropriate dots on the "menu" on the left-hand side of the display, the student can see a list of all the logically-possible faults eliminated so far or eliminated on the last front-panel test he performed. By touching the dot on a particular control on the screen, he can see a blowup of that control, observe, say, whether it is on or off, and change its setting if he wishes. Every time the



•TOTAL ELIM
•LAST ELIM
•REPLACE
•SETTINGS
•DONE
•UP
•SLIDE
RANGE SELECTOR
BATTLE SHORT
POWER
OVERHEAT
PANEL DIMMER
ON
ON
RADAR SEL
RANGE RINGS/ MILES
PLOTTER ALARM
OFF
OFF STBY
ON
OC RES

FIGURE 3


RANGE SELECTOR
PANEL DIMMER
OVERHEAT
BATTLE SHORT
POWER
OFF
ON
ON
RADAR SELECTOR
OFF
ALARM OFF
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OFF
1
2
5
10
20
30
PLOTTER
ON
DC RESTORER
350
0
10
20
30
40
50
60
340
330
320
310

FIGURE 4

student changes the setting of a control, the computer simulation operates as the real equipment would operate with the control in the new setting.

The specific details of the TASKTEACH program allow the student to perform tests on the simulated equipment and isolate the fault. The student can get practice with a large number of faults, without involving the expense and time of having a technician set up each fault by hand. And, most important, innovative pedagogical aids, emanating from and contributing to our knowledge of how concrete visual imagery is involved in effective learning, have been programmed into the procedure.

The intention, when developing the TASKTEACH approach, was not to do the best possible job of teaching how to maintain the SPA-66, but rather to develop a generalized maintenance trainer into which the data base for different equipments can be introduced in a sort of "plug-in" fashion. At the present time, Rigney is working cooperatively with the Field Management Group, Electronic Technician Training System Improvement Program at the Service Schools Command, San Diego. They will use TASKTEACH to teach maintenance skills on ships' communication gear of concern to the San Diego group. That group is providing the data base on the equipment, and Rigney's group is interfacing that data base with the TASKTEACH logic. This precedent-setting agreement illustrates one way in which potential users can become involved constructively in research which is quite basic. It will allow Rigney to demonstrate

the generality of the TASKTEACH concept and will provide the occasion for field-testing it.

Learning to program a computer is a different sort of hands-on task, involving problem-solving skills, rather than elimination of logical alternatives, as in electronic troubleshooting.

Richard Atkinson's research group at Stanford has developed an innovative program for teaching the BASIC computer language. The work on BIP, the BASIC Instructional Program, is being carried on by Keith Wescourt while Atkinson serves as Deputy Director of the National Science Foundation. Figure 5 illustrates the structure of BIP.

The student communicates with two parts of the BIP program at once. The Curriculum Driver module selects and presents the most appropriate available curriculum element, in this case a programming "task," which the student is to solve by writing an appropriate BASIC program. The student's program is run by BIP's BASIC interpreter. BIP's interpreter is designed for pedagogical purposes and offers the student informative error messages, on-line references to the extensive student manual, and interactive debugging facilities.

The major research advance incorporated in BIP's design is the Curriculum Information Network. The network relates the tasks that comprise the curriculum to the procedural skills to be mastered by the programming student. The student model reflects the state of learning of each skill in the network. Given the state of the student model, the

THE STRUCTURE OF THE BASIC INSTRUCTIONAL PROGRAM (BIP)

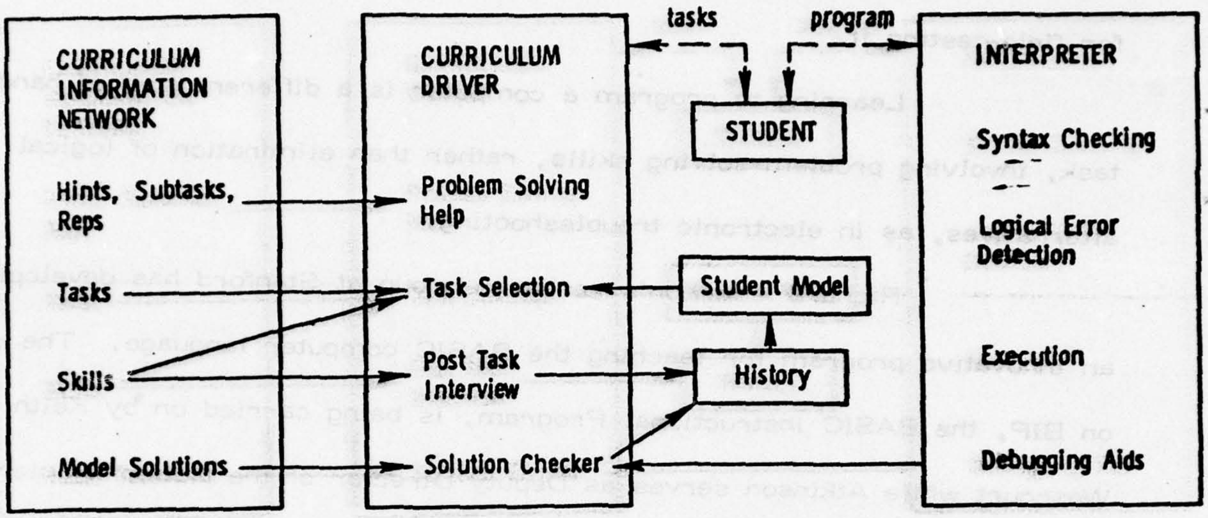

FIGURE 5

task-selection algorithm uses the structure of the Curriculum Information Network to select the task that is appropriate for that student at that point. The coordination of information in the network, the task selection algorithm and the student model determines the nature and effectiveness of BIP's dynamic sequencing through the curriculum. The current research emphasis is on introducing systematic modifications into each of these components and evaluating the changes brought about in the system's behavior.

Particular emphasis is being placed on the investigation of systematic modifications in the Task Selection Algorithm. Different Task Selection Algorithms will be devised and data from hundreds of students who have taken the course under the present Task Selection Algorithm used as input for simulation. The output of the simulation will be the instructional outcomes which would have occurred if those students had taken BIP with each of the new Task Selection Algorithm. As this research goes on, the same research group, under funding from the Navy Personnel Research & Development Center is developing the BIP program further as an actual prototype instructional program.

An important focus of our program involving cognitive psychology in an instructional mode is what has been called generative computer-assisted instruction (CAI). Since that term may convey an inaccurate impression to some of you, I'll try to give a general sense of what I mean by it. In generative CAI, the data base, the information that is to be conveyed to the student, resides in the computer in some

organized fashion. Sophisticated techniques are then used to decide what information from the data base to present to a student at any given time, and in what form, based on the entire interaction with the student up to that time. This may sound a little abstract, so let me illustrate. Suppose the subject matter is South American geography; a great deal of information about South American geography is stored in an organized representation, say a semantic network representation, within the computer. Sophisticated techniques, many drawn from the world of artificial intelligence, are used to extract the meaning from student inputs, and other sophisticated techniques, derived from analysis of successful strategies human tutors use, are used to decide what information to present, what questions to ask, and so forth.

The example I just gave is not hypothetical. It is a description of the SCHOLAR system, used in the work of Allan Collins at Bolt, Beranek, and Newman. To be sure, SCHOLAR is a sophisticated system from a computer-science point of view, involving, for instance, an extremely clever and innovative scheme for drawing computer graphics maps and coordinating information about places on the maps with verbal information in the data base about those places. But the interesting questions from the standpoint of cognitive psychology lie in the nature of the representation of knowledge people have, which might be used for such systems, and in the nature of tutorial strategies people use successfully, which can be incorporated in such systems. Collins, while not neglecting the representation

question, has given major attention to the study of tutorial strategies. He is moving into the study of tutoring causal knowledge. This sort of knowledge is pervasive aboard ship, a part of every job from task force commander down to unrated seaman. It is a vital part of the technical skills jobs aboard ship. For this reason, one vehicle for the study of tutoring causal knowledge will likely be a complex shipboard system, perhaps the steam propulsion system.

At this point, however, Collins is working with dialogues between human tutors and live students, and abstracting techniques, in the form of "rules" for tutoring causal knowledge, which will be included in his forthcoming generative CAI system for causal knowledge. For instance, assume that the problem posed for the student is to figure out why there is heavy rainfall along the Oregon and Washington coast. There is a whole causal chain that leads up to this, and the system would probe the student until the entire chain is discussed. An important part of this strategy is to pick places, such as the Southern California coast, where there is very little rainfall, so that the student will learn what causes little rainfall as well as heavy rainfall. When he has learned the factors that cause rainfall, then the system should force him to decide whether there is likely to be much rainfall in places like northern or southern Chile, which the student is unlikely to know about. This will teach him to use his knowledge in a predictive way and to ask the right questions when he does not know the values for the relevant factors.

While Collins is primarily concerned with tutorial strategies, Donald Norman of the University of California at San Diego has as his primary concern the representation of knowledge in people, and hence in the generative CAI systems he is building. Norman and his colleagues have developed, for instance, a model for representing the knowledge one might have about, say, the western campaigns of the American Civil War. It is a rigorous semantic network representation for story-like information which details the relationships between different concepts in memory. This Story Grammar Structure has served as the basis for some very successful teaching of Civil War history. A task of paramount importance for Norman's group has been revision of the representation model, based on specific successes and failures of teaching which emanated from it. At this point, a more flexible sort of representation system, called Knowledge Modules, is being developed. A good deal of the upcoming work will be concerned with providing a theoretical base for the entire concept of knowledge modules, along with a rigorous delineation of their properties.

You've seen work asking fundamental questions about several different cognitive processes. It certainly doesn't exhaust all the work we have in the cognitive process domain, nor even all the work these four investigators are engaged in. It should, however, give you a bit of the flavor of some of our efforts in the realm of cognitive psychology in an instructional context.

ARTIFICIAL INTELLIGENCE TECHNIQUES IN ELECTRONIC TROUBLESHOOTING TRAINING: DEVELOPMENT AND EVALUATION

Dr. Bruce W. Knerr

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INTRODUCTION

In 1974 the US Army Research Institute for the Behavioral and Social Sciences (ARI) initiated a program to develop what we later came to call an Adaptive Computerized Training System (ACTS). As we envisioned it, the ACTS would be a rather basic application of artificial intelligence techniques to training, that is, relatively unsophisticated and requiring a small amount of computer memory. The resulting system is designed to train electronic troubleshooting procedures. The student's task is to troubleshoot a complex electronic circuit by making final verification measurements. All equipment is simulated by the ACTS. The heart of the system is an adaptive computer program which "learns" the student's decision utility structure, compares this structure to that of an expert, and when complete, will adapt the instructional sequence and feedback to eliminate discrepancies. An Expected Utility (EU) model of decision-making is the basis of the models of both the student and expert troubleshooters.

The decision to proceed with this project was based on our belief that training can be made more effective or efficient if it is adapted to the individual student. Historically, Programmed Instruction (PI) was an early attempt to provide such individualization. As originally developed by Skinner (1960), and widely adopted, the same material was presented to all students in a linear fashion. Individualization was provided only in

the sense of self-pacing, that is, permitting each student to proceed at his or her own rate. Other versions of PI (e.g., Crowder, 1960) included branching which was dependent on student responses, thus providing greater individualization by varying the material to which the students were exposed, as well as permitting variations in rate. In the absence of student record-keeping methods, however, elaborate branching techniques were not practical.

Use of computers for instruction (Computer-Assisted Instruction, or CAI) provided the record-keeping capability to provide more elaborate branching. It also provided a greater variety of types of use. Simulations and drill and practice became possible in addition to instruction in the tutorial mode. However, it now appears that many of the adaptive capabilities of CAI are under-utilized. All too frequently, CAI is used as an automated PI text. The reasons for this are complex, but a major factor appears to be the difficulty of creating highly adaptive CAI lessons.

Given that adaptive lesson materials are of value in the training process, it is easy to see the advantages of a system that can itself modify feedback and the instructional sequence on the basis of individual student performance, without the necessity for programming all of the contingencies. In order to provide this adaptability, we turned to the use of "artificial intelligence" techniques.

Despite the previous emphasis on evolution in the fields of education and training, the basic model for the ACTS came from neither of those fields, but from a decision-aiding model for control system operators. Personnel from Perceptronics, Inc. had, prior to 1974, been working on two projects which used adaptive models in decision-making (Freedy, Weisbrod, May, Schwartz, & Weltman, 1973; Davis, Weisbrod, Freedy, & Weltman, 1975; Freedy, Steeb, & Weltman, 1972; Weltman, Steeb, Freedy, Smith, & Weisbrod, 1973). In 1974 the same organization, under contract to ARI, began a project to modify their system for use in a training context. A detailed description of progress to date is provided in two reports: May, Crooks, Purcell, Lucaccini, Freedy, and Weltman (1974); and May, Crooks, and Freedy (1976).

DEVELOPMENT

ACTS STRUCTURE

Perhaps the best way to describe the ACTS is to begin by looking at its four major components. These are:

(a) the Task Model,

(b) the Student Model,

(c) the Expert Model, and

(d) the Instructional Model.

Task Model

This is a model of an electronic circuit in which faults can be simulated. The circuit currently being used is a modular version of

the Heathkit IP-28 power supply. The modular version, which has only 10 components, was used to make it more similar to Army electronic maintenance tasks. The model uses a table-driven simulation of the fault symptoms. This means that once the fault is selected, the computer reads values for the test measurements from a table. Complete simulation of the circuit is not required. The results are presented to the student in a "semi-interpreted" form (i.e. "normal", "high", "low").

Student Model

This is an Expected Utility model of the student's decisions which permits adaptive estimation of his utilities for various test measurements. As the student troubleshoots, the model is adjusted to match his performance.

Expert Model

The expert model is an Expected Utility decision model of an expert troubleshooter. Unlike the student model, the expert model is adjusted only while the expert is "training" the model. The model is fixed while the student is being trained.

Instructional Model

The instructional model consists of the adaptive instructions provided to the student. Instruction is based on a comparison between the student and expert models. It is focused on the student's decision making process. It is assumed that the student knows electronic theory and simple procedures, like taking test measurements.

ACTS SEQUENCE OF OPERATIONS

We can take a closer look at some of these components through an overview of the training process. Let us assume, at the start, that the task model, that is, the circuit simulator, has already been developed.

As noted previously, the ACTS is based on an Expected Utility model of troubleshooting performance. According to this model, troubleshooting behavior is a product of two factors:

(a) the probability that a particular component is faulted, and

(b) the utility of the information that would be provided by each possible measurement in a given situation.

The training process starts by obtaining from an expert troubleshooter a list of prior probabilities of the form:

The probability of a particular measurement outcome, given a certain fault.

For example:

Given that the transistor in module D is shorted, the probability that the output voltage of module E will be high is .70.

These prior probabilities are then aggregated to form conditional probabilities of the form:

The probability of obtaining a particular measurement outcome given the previous measurement history.

For example:

If the output voltage of module K is low, the probability that the measurement of the output current of module L will be normal is .40.

The expert then solves, on line, a series of troubleshooting problems. As he does so, the <u>expert model</u> "learns" his utilities for the various measurements. It does this by observing the expert's choices among the options available to him at each step in the troubleshooting process, and adjusting the estimates of his utilities for each option so that the estimated expected utility for his choice is a maximum.

The expected utility function used is:

$$EU_j = \sum_i^n \alpha_{ij} P_{ij} U_{ij} .$$

where

EU_j is the expected utility of action A_j

P_{ij} is the probability that result i, of a set of n results, will occur if action A_j is selected

U_{ij} is the relative utility of result i of action A_j

α_{ij} is the information gain resulting from the occurrence of result i of action A_j

Note that P_{ij} is a conditional probability aggregated from the probabilities previously elicited from the expert. α_{ij}, the information gain component,

is based on the proportion of possible faults that would be eliminated by the occurrence of result i.

Thus, when the expert starts the troubleshooting process, his probabilities are known and have been entered into the model. The values of the information gain component can be calculated directly and entered into the model. This leaves two sets of unknowns; the expected utilities for each possible action (EU_j), and the utilities for each result (U_{ij}).

Initially, the utilities are set at a common value, and the expected utility of each alternative action is calculated. If the action with the highest expected utility is the same as that selected by the expert, no change in the estimated utilities is made. On the other hand, if the two are different, the utilities of the action chosen by the expert are "rewarded", or increased, and those of the action chosen by the model are "punished", or reduced. This process continues until the estimated utilities become stable. This will occur when the expert model is able to predict the choices of the expert accurately.

At this point, the expert is no longer needed. The expert model, having been "trained", replaces the human expert. Now the system is ready to begin training the student. As did the expert, the student begins to troubleshoot. As he does this, he has access to the aggregated probabilities produced by the expert.

EVALUATION

A one-year effort was required to develop the basic system software for the aiming. Since the [illegible] was completed at the end of 1975, the system has continued to undergo modifications and, in many respects, is still developmental. For example, the development of the adaptive instructions is just beginning, and the oresentation of different troubleshooting

Now we introduce the <u>student model</u>. As the student solves a series of troubleshooting problems, the student model, which functions in the same manner as did the expert model, learns the student utilities. When the estimated student utilities begin to stabilize, the utilities of the student model and those of the expert model are compared. If discrepancies between the two sets of utilities are found, instructions are provided to the student to bring his utilities closer to those of the expert.

OVERVIEW OF STUDENT ACTIONS

The student takes the following actions as he solves a troubleshooting problem. First, after a problem is presented to the student on the display of his terminal, he decides which of the alternative actions to take. He considers in this decision the probability that each of the alternatives will help him to isolate the fault, and the cost of each alternative action. (Costs are presented to the student in dollar amounts, and reflect the amount of time that would actually be required to take a particular action on a real circuit.) Based on these considerations, the student chooses a measurement. The display then shows the results of the measurement requested by the student. This process continues until the student feels that he has isolated the faulty circuit module. At that time he simulates replacement of the module, and makes verification measurements to determine that the circuit is functioning correctly.

The student display, as it appears at the start of a problem, is shown in Figure 1. It has three major components:

(a) the circuit diagram,

(b) the legend of measurements and costs, and

(c) the communication area.

The circuit diagram could, if necessary, be presented to the student in printed form, thus simplifying the display requirements. The legend of measurements and costs provides the student with a list of all possible measurements, their relationship to the circuit diagram, and their costs. It also shows the results of all measurements previously taken. The communication area is used to inform the student of the options available to him, and to respond to his requests for information.

Figure 2 shows a display for a partially completed problem. The outcomes for the measurements that the student has taken are shown in the legend of measurements and costs area. The probabilities of measurement outcomes for actions the student is considering are shown in the communication area.

EVALUATION

A one-year effort was required to develop the basic system software for the ACTS. Since that was completed at the end of 1975, the system has continued to undergo modifications and, in many respects, is still developmental. For example, the development of the adaptive instructions is just beginning, and the presentation of different troubleshooting

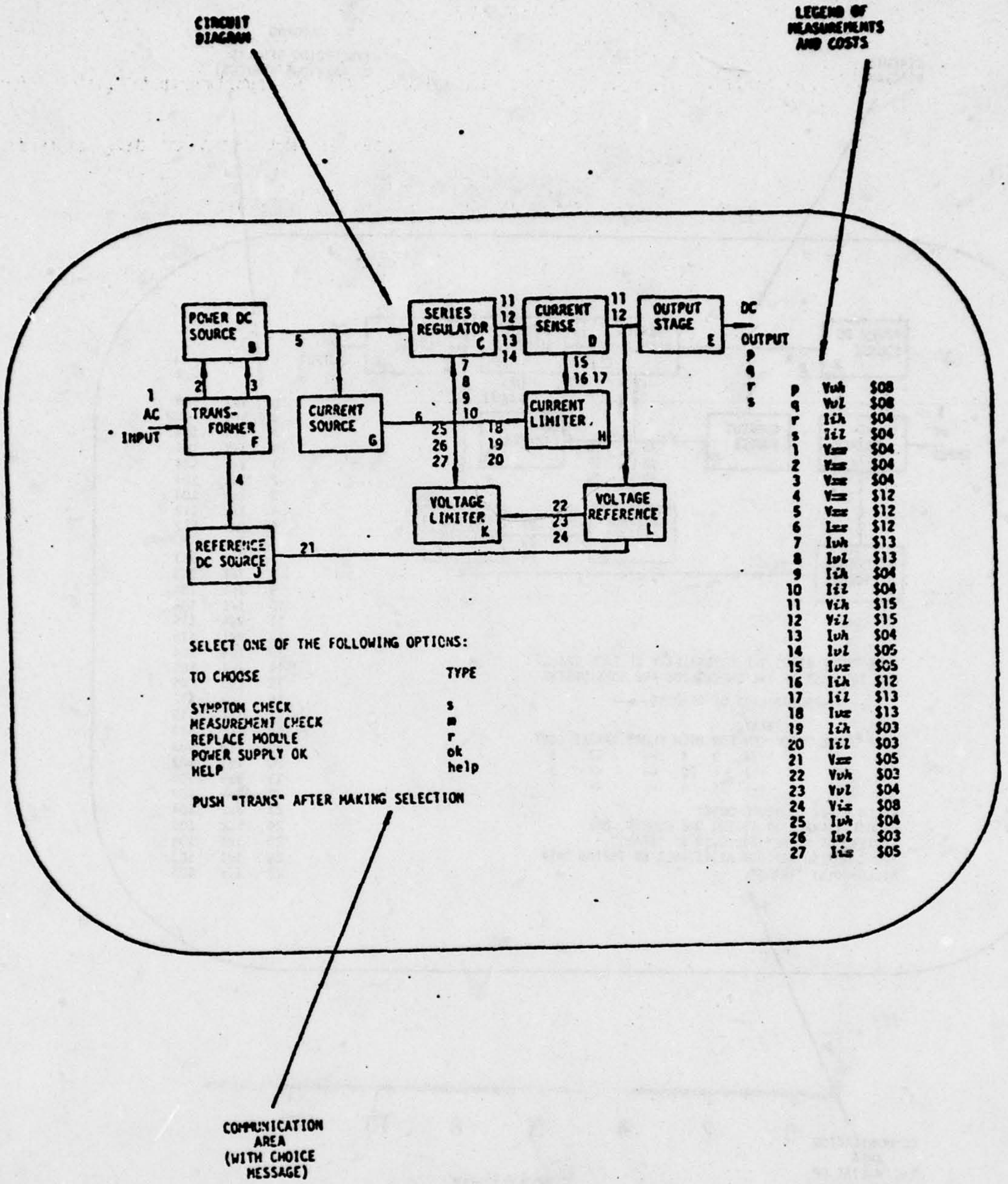

Figure 1. Student display at the start of a troubleshooting problem.

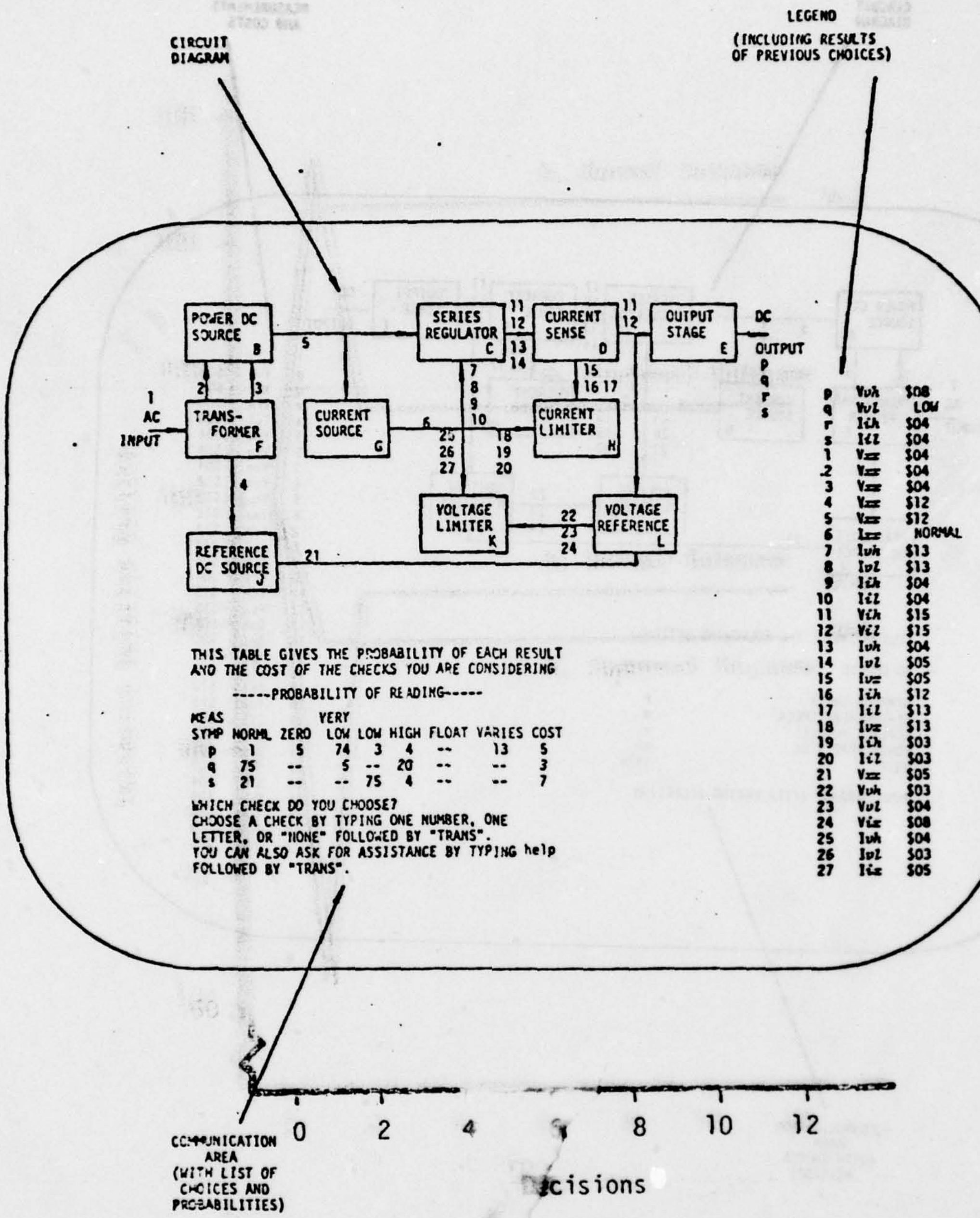

Figure 2. Student display of a partially-completed troubleshooting problem.

Figure 3. Estimated relative utilities for normal and abnormal outcomes of two measurements (6 and 9) as a function of the number of decisions.

problems, depending on the state of the student's utilities, is an issue that has yet to be addressed.

What progress in the evaluation of the ACTS has been made? Some necessary, but not sufficient, requirements have been met.

The most basic requirement is that the utility estimation algorithms must operate correctly. This applies to both the expert model and the student model. Several tests of these algorithms have been conducted.

The first were conducted using pairs of selected measurements. An arbitrary set of utilities was chosen for the normal and abnormal outcomes of the two measurements under consideration. A troubleshooting problem was initiated and an expert used the arbitrary utilities to calculate the expected utilities of those two measurements, according to the EU model described previously. He always chose the measurement with the greater expected utility. This process was repeated for several problems using different measurements. Figure 3 shows the change in the utilities for the two outcomes (normal and abnormal) of two selected measurements. In this case, one of the utilities had an imposed value of two and the other three had an imposed value of one. This figure shows rapid stabilization (the utilities did not change after the second decision), and a rank ordering similar to that of the imposed values. These tests indicated that the utility training algorithm was operating correctly for pairs of isolated measurements.

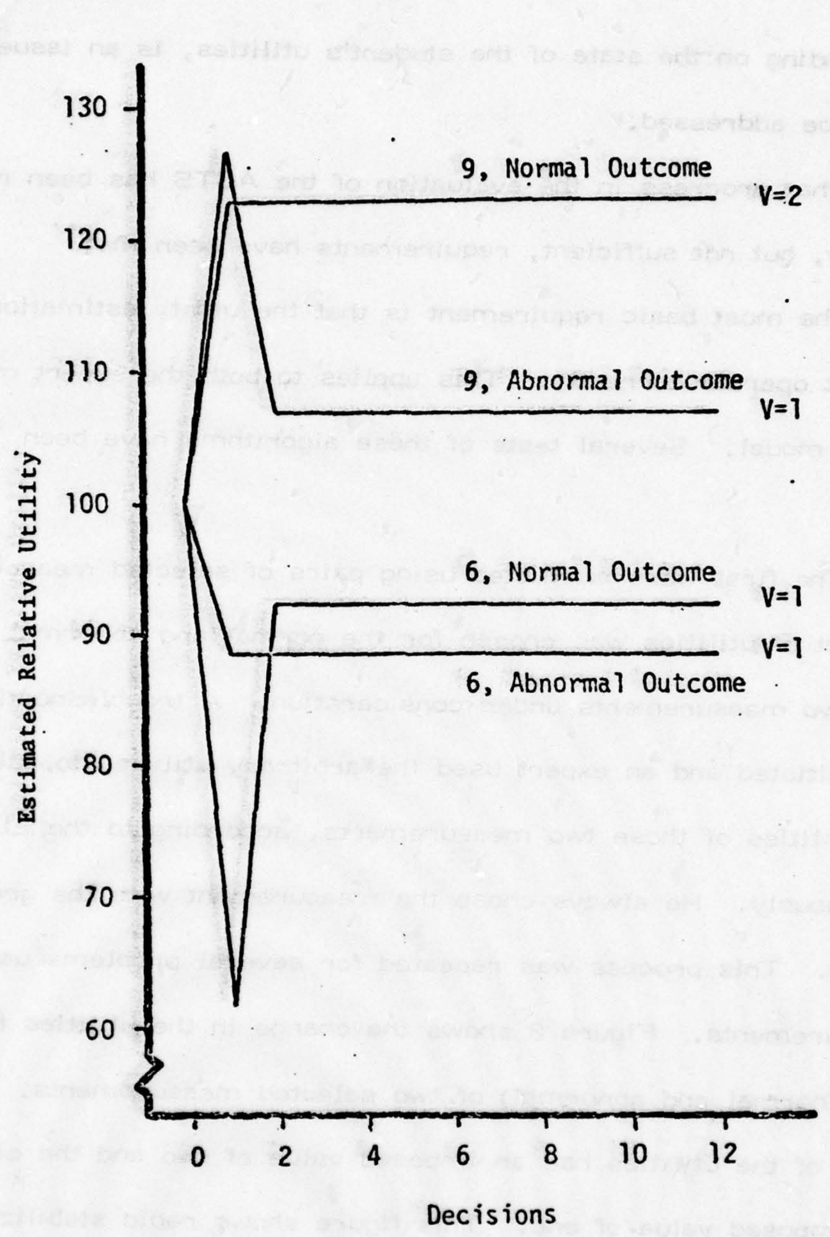

Figure 3. Estimated relative utilities for normal and abnormal outcomes of two measurements (6 and 9) as a function of the number of decisions.

Subsequent tests were made by an expert who used a consistent overall decision strategy. Most of the available measurements were used. Following 14 problems (70 measurement-selection decisions) the utilities that had been adjusted stabilized at levels which corresponded to their ranking in the decision strategy used by the expert.

The same utilities were also inserted in a "simulated student" program to provide an additional test of the utility adjustment algorithm under conditions where the student utilities were "known" and the decision maker was completely consistent. The simulated student is a routine which troubleshoots the circuit using any set of utilities with which it may have been programmed. It always chooses the action with the highest expected utility. The resulting utilities produced by the utility estimation algorithm were in a similar rank order to the simulated student's utilities.

Since the expert model and the student model are, in essence, identical, it can be assumed that if the expert model functions properly, so does the student model. Nevertheless, this assumption was checked by conducting a test, similar to that just described, of the adaptive student model. The success of the student model in predicting the actions selected by the simulated student model is shown in Figure 4. Accuracy increased rapidly during the first 80 decisions (approximately 18 problems), and perfect success was achieved after 210 decisions (45 problems).

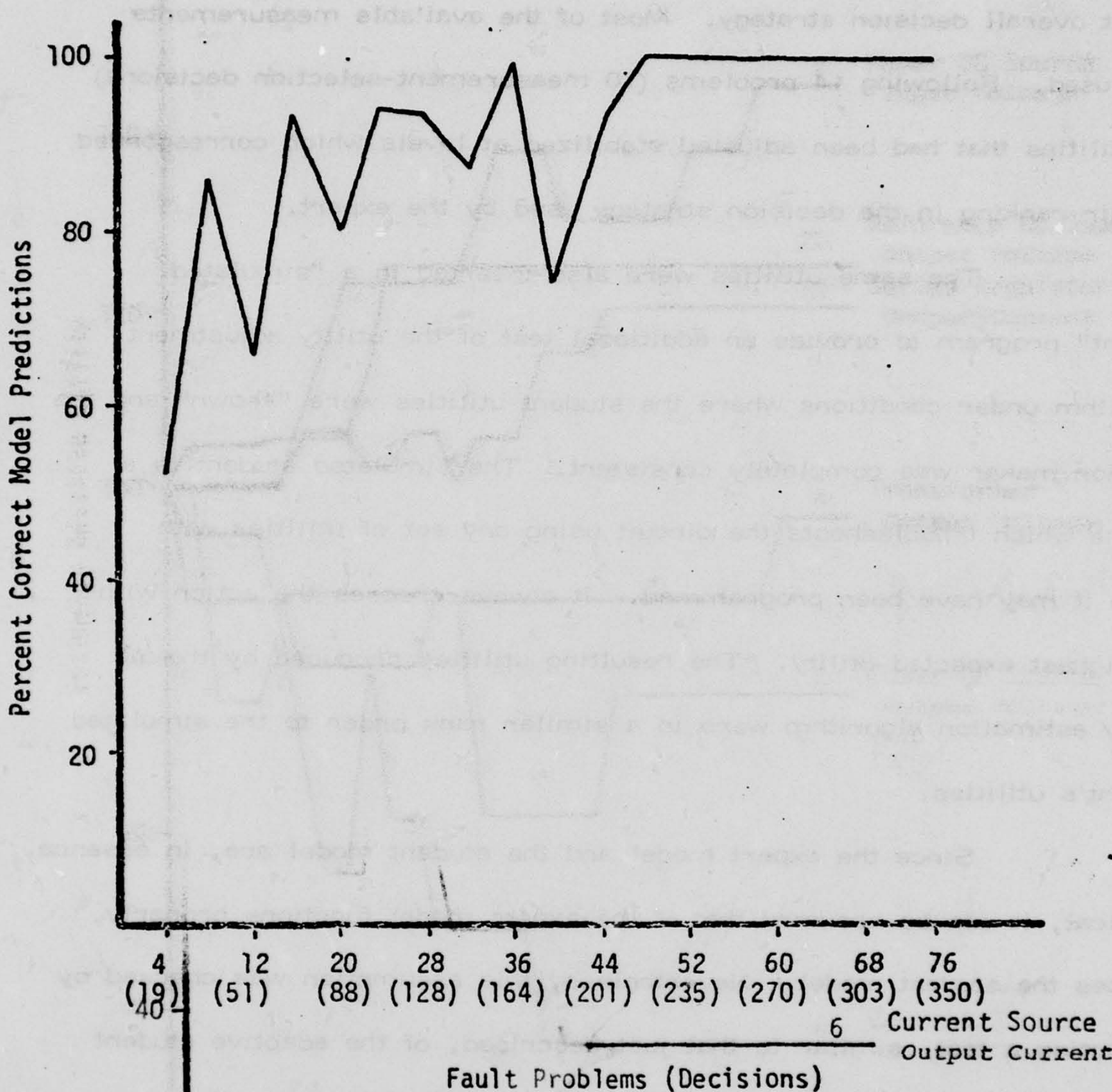

Figure 4. Student model predictive success during simulated student performance.

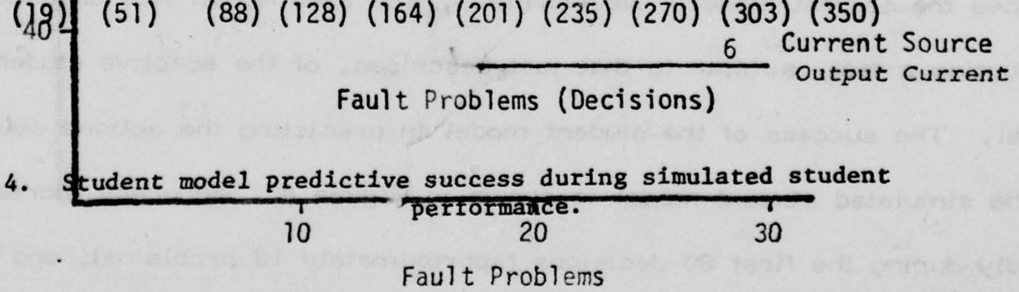

Figure 5. Estimated relative utility for key measurements as a function of training session.

The tests described above indicated that the adaptive utility-estimation algorithms operated correctly when the students or experts made decisions consistently. The next series of tests was conducted to determine how those algorithms performed when the decision-makers were less than perfectly consistent.

The first test with a "real" person used an expert electronics technician, who solved 30 troubleshooting problems using the ACTS while the utilities of the adaptive model were adjusted. In a post-session interview, he was asked about his reasons for selecting specific measurements and his estimates of the importance of those measurements. Those which he indicated had critical importance in troubleshooting were identified as the key measurements. Figure 5 shows the adjustments to and stabilization of his utilities for normal measurement outcomes of these key measurements. Their rank order is the same as his verbal ranking of their importance.

A subsequent study was conducted to examine the performance of experienced electronic technicians. Eight students who scored high on a written electronics knowledge test were given 4 1/2 hours of experience on the ACTS, divided into three sessions. During the second of these sessions, they used the expert's estimates of action outcome probabilities as an aid in their selection of troubleshooting actions. During the first and third sessions the probabilities were not provided to the students.

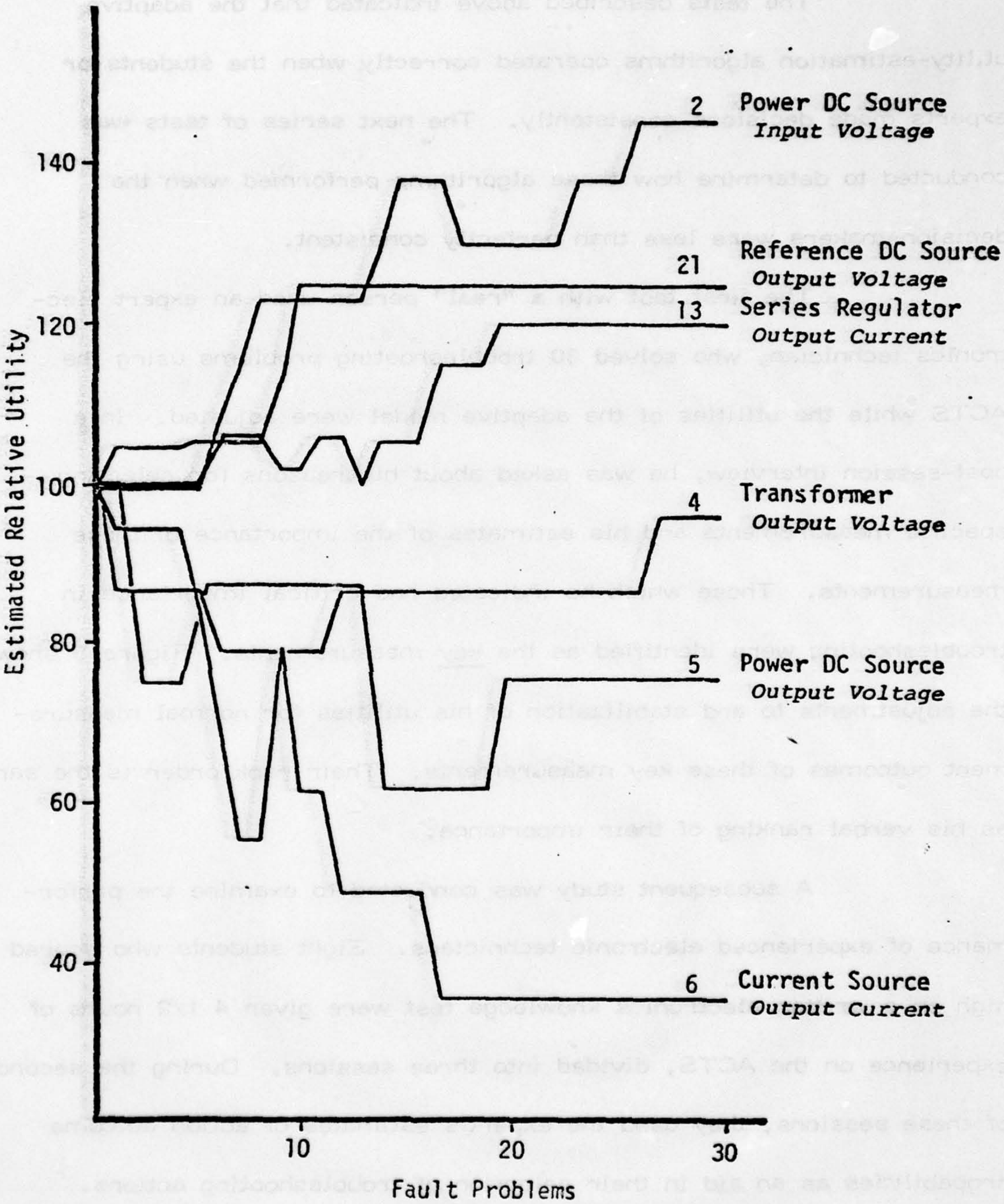

Figure 5. Estimated relative utility for key measurements as a function of training session.

The students improved their decision-making speed throughout the three sessions. The mean and range of decision time performance are shown in Figure 6. Figure 7 shows student decision efficiency measured in decisions per problem. Here we see the student's dependence on the outcome probabilities provided by the expert. When the probabilities were withdrawn in the third session, the student's decision efficiency decreased and they required about 60% more decisions before isolating each fault.

The mean predictive success of the adaptive student model was also assessed during this test, as shown in Figure 8. During the second session, when the outcome probabilities were presented, the model predicted 75% of the students' choices correctly.

At this point in the evaluation process, the following conclusions can be made. First, the adaptive utility estimation algorithm can predict, after practice, the performance of a consistent decision maker. Second, the adaptive utility estimation algorithm accurately rank orders the utilities of an expert technician. Third, the presentation of outcome probabilities improves both student performance and the predictive power of the student model. Finally, student performance improves with practice on the system in the absence of any feedback regarding utilities.

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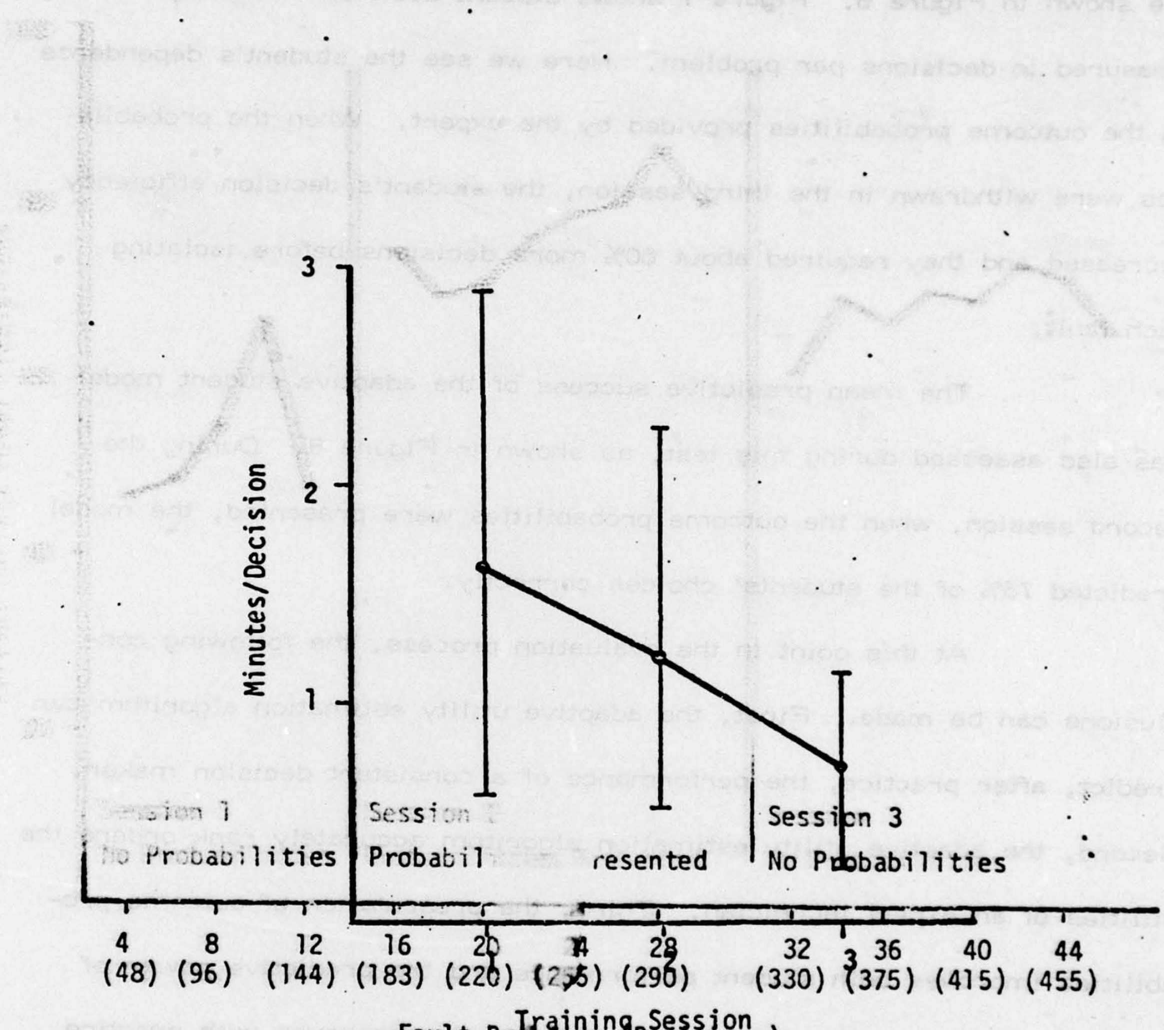

Figure 6. Student decision time as a function of training session.

Figure 8. Student model predictive success as a function of fault problems.

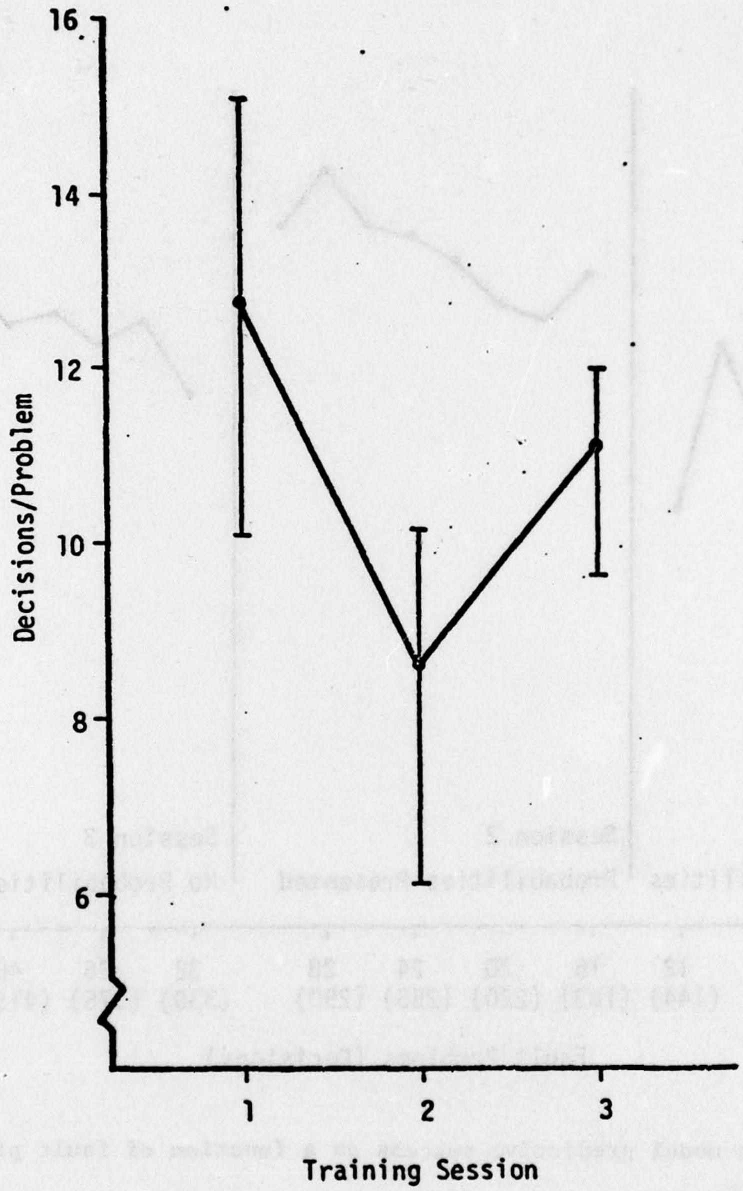

Figure 7. Student decision efficiency (decisions/problem) as a function of training session.

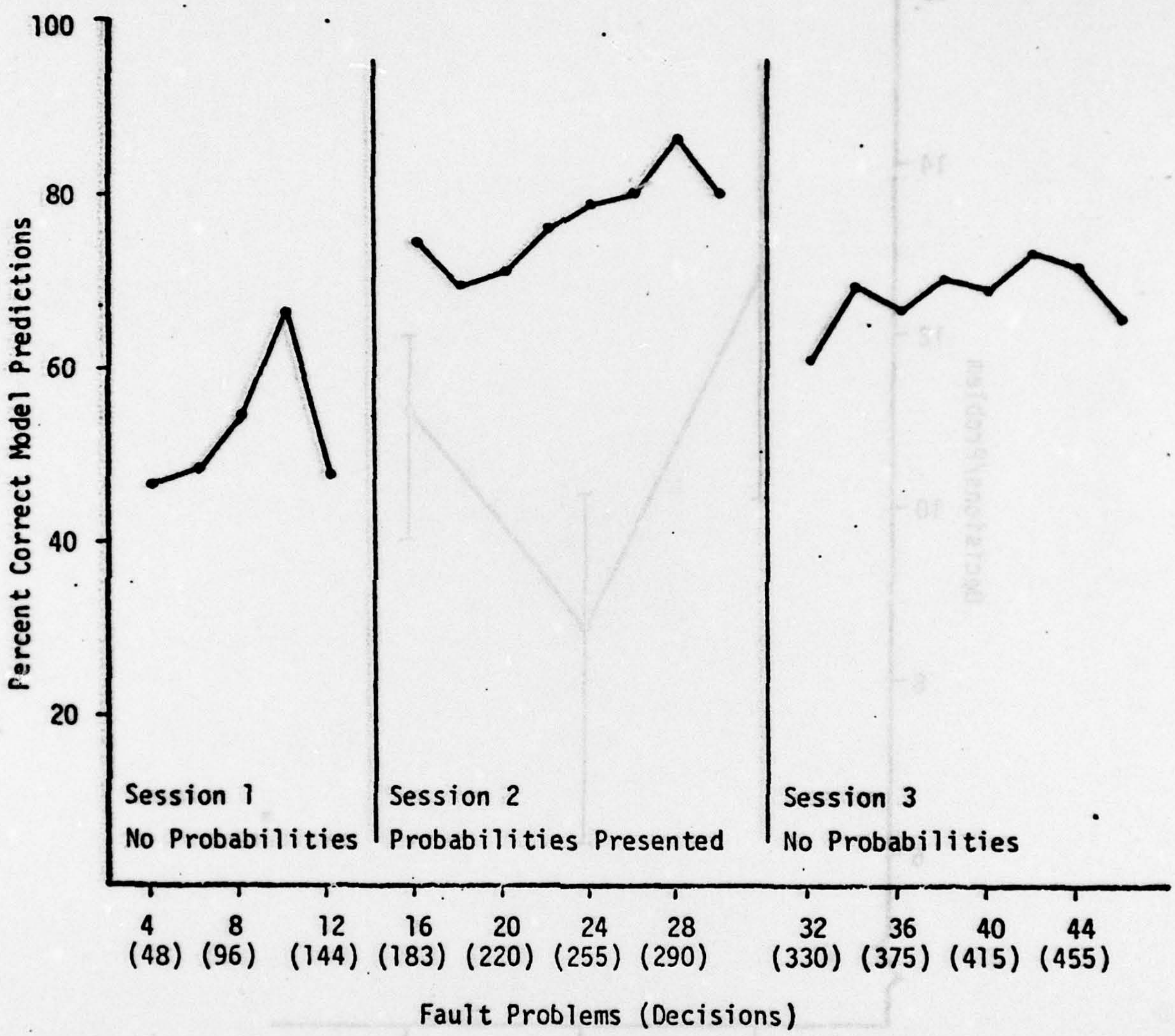

Figure 8. Student model predictive success as a function of fault problems.

FUTURE DIRECTIONS

Now that progress to date has been described, it is time to turn our attention to future directions and goals. There are three major steps to be taken before the ACTS will be ready for implementation in an Army training environment. These are:

(a) further development of utility-based feedback,

(b) an evaluation of training effectiveness and transfer, and

(c) evaluation of the ACTS in an operational setting.

The reason for starting this project was to be better able to adapt instruction to the individual student. The mechanism by which this is to be accomplished is feedback to the student based on his utilities. Further development in this area is required. One set of instructions for the students has been developed which instructs the student on the use of key measurements, dependent on his utilities for those measurements. That is, if his utility for a certain measurement is discrepant from that of the expert, he is provided with more information on when and how to use that measurement. Results to date, while very limited, indicate that those instructions sometimes, but not always, move student performance in the desired direction.

Following development of the adaptive instructions, an evaluation of the training effectiveness of the entire system is required. This will include evaluation of transfer to the actual equipment, as well as evaluation of troubleshooting performance on the circuit simulator.

The final step will be an evaluation of the ACTS in an ongoing course of instruction at an Army school. It will be conducted on a large scale, and will permit assessment of long-term retention of the skills involved, and possibly the impact of ACTS training on subsequent troubleshooting training.

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